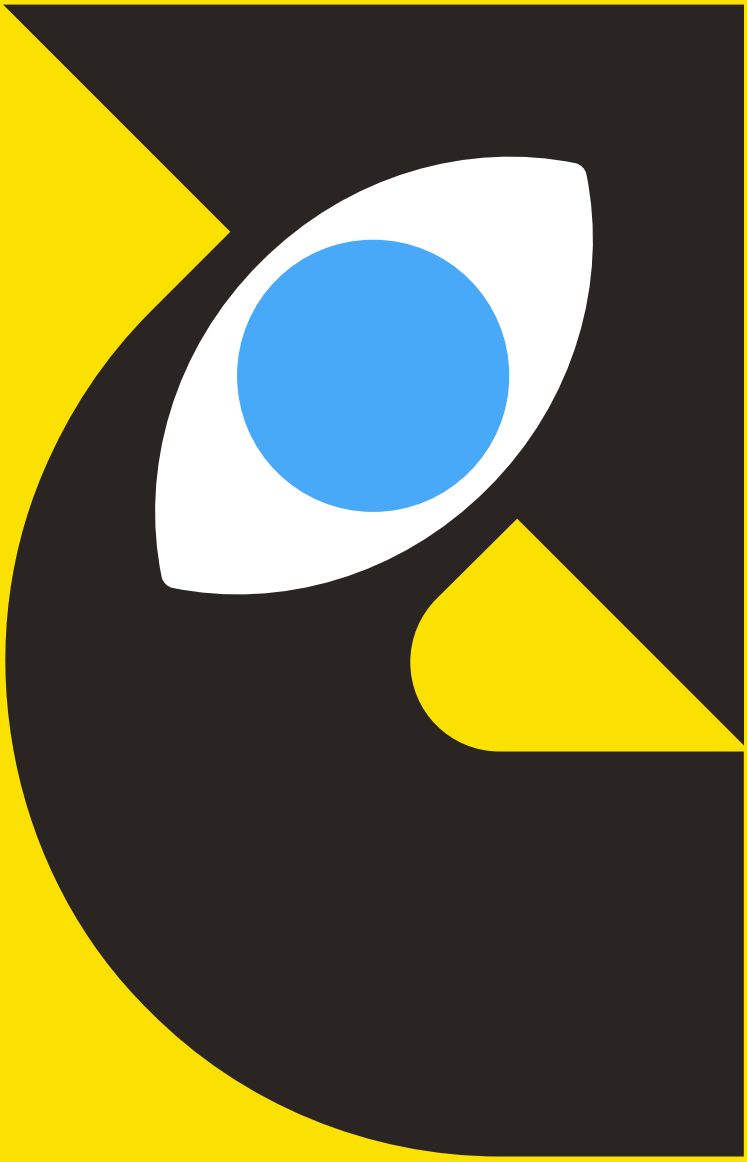
GLOBAL RESEARCH IN ACTION



Selected papers from the World Design Congress London 2025

WDO WORLD DESIGN ORGANIZATION

About this publication

Exploring the theme of *Design for Planet*, WDO's biennial World Design Congress was hosted by the Design Council and took place in London (United Kingdom) from 9–11 September 2025, bringing together design, business, education and sustainability visionaries from around the world to explore design-led solutions to the climate crisis.

The following presents the papers selected for publication as part of the World Design Congress 2025, highlighting cutting-edge research, innovative practices and critical reflections at the forefront of three themes: Shifting Paradigms – From Extractive to Regenerative Design; Economy and Design – Innovating for Circular Economies and Policy and Design – Shaping a Global Response.

Showcasing diverse perspectives on sustainable design, circular economy strategies, climate-responsive approaches, and socially inclusive solutions, the papers reflect the depth and breadth of contemporary design and offer a window into the emerging ideas and methodologies that are shaping the future of design for planetary well-being.

To learn more about the World Design Congress 2025 and see the posters presented, please visit: wdo.org/programmes/world-design-congress/34worlddesigncongress

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Shifting Paradigms — From Extractive to Regenerative Design

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Ana Garcia Schwebel

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London Metropolitan University (United Kingdom)

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Maria del Mar Sanz Abbud
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Jorge Benitez Luna
Norma Patricia Diaz Enriquez
Lorena Fuentes Lamas

Institution

Universidad Iberoamericana (Mexico)

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Rita Morais
Brenda Parker
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Institution

University College London (United Kingdom)

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Development Trusts Northern Ireland (United Kingdom)

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Eleni Mente

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Daiwa Anglo-Japanese Foundation
The Great Britain Sasakawa Foundation (United Kingdom)

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Ruth Wright-Palmer

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GLDN Studio (United Kingdom)

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Julie Johnstone
Katie Haas
William Stratton
Hilary Mulford
Dongni Ma
Yani Pohl

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Great Ecology (USA)

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Dr. Sofie Boons

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HairCycle

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Tam Preston
Dr. Rosie Hornbuckle

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Kallpa Bench

Danilo Calvache

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Andrew Walters
Dr. Katie Beverley
Jo Ward
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Waste, a Treasure: Designing Industrial Upcycling

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ROKA Circular by Design (Türkiye)

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Policy and Design — Shaping a Global Response

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Duncan Brown

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Electronic Dream Plant (United Kingdom)

Community Resource Green Maps

Kelly Salchow MacArthur

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Michigan State University (USA)

Form Follows Function: Polymerization as a Policymaking Prototype

Michaela Mei Quiñones
Tarhata Mariano

Institution

Medium PH (Philippines)

The Satoyama Becoming a Villager: Designing AI-based Collaborative More-than-human Governance and Social Systems in Rural Japan

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Dr. Thomas Garvey

2023-2025 WDO President

Since 1959, WDO's World Design Congress has brought together design leaders and thinkers from across the globe to strengthen and guide the future of design. In 2025, we partnered with WDO Promotional Member the Design Council to bring our community to London (UK) and explore the ideas, insights and innovations driving the global Design for Planet movement.

What emerged throughout our time in London was a powerful reminder: design for a better world begins and ends with design for the planet. Collaboration across disciplines, sectors and contexts – including academia and industry – is essential. Designers, researchers and industry professionals alike must show leadership that reflects the full complexity of today's environmental realities.

From circular economy strategies to regenerative technologies and community-centred initiatives, Global Research in Action presents the papers selected for publication as part of the World Design Congress London 2025. This global collection highlights a remarkable range of work from scholars and practitioners committed to designing for planet. We extend our deepest gratitude to all authors for their contributions, as well as to our World Design Congress 2025 Review Committee, chaired by Professor Anastasios Maragiannis.

At the heart of this publication is our belief that progress emerges when knowledge is shared. These papers therefore form a collective resource that will continue to spark new partnerships, challenge assumptions and nurture the next generation of design-led transformations.

Minnie Moll

Chief Executive
Design Council (United Kingdom)

The Design for Planet mission was born from the belief that design is a critical tool for the green transition. Not only because 80% of a product's environmental impact is determined at the design stage, but because designers can translate scientific and technological innovation into inclusive products, services and places. They connect knowledge across professions and cultures that can drive behaviour change and shape our future.

The World Design Congress 2025, hosted at London's Barbican Centre, was a melting pot of ideas. Welcoming 1,000 delegates from 88 countries (designers, businesses, policymakers, academics, educators, students and climate NGOs), it demonstrated the power of design for circularity, zero emissions and biodiversity, while sharing emerging research and practice from academia to industry. Professor Christopher Smith highlighted the UK Government's investment in design-led research and innovation through the Future Observatory programme.

This document brings together papers from across the world, sharing cutting-edge design research, from transforming disused mining shafts in China into geothermal energy sources and biodiverse wetlands, to rewilding urban spaces and reimagining governance through design. These projects show how new ideas are already being translated into action.

One of the big narratives at the Congress was the need to shift our perspective from human-centred to planet-centred design. I'm excited to see how the global design community can now take this vital step in turning ideas into action and regenerating our world.

Prof. Anastasios Maragiannis

World Design Congress 2025 Review Committee Chair
Pro Vice-Chancellor of Creative Education, University for the Creative Arts (United Kingdom)

Design today stands at a threshold, between what we create and what we must now repair. The role of the designer is no longer confined to shaping form or function; it has become an act of stewardship, of questioning how our work participates in planetary systems and social ecologies.

The World Design Congress 2025 saw the highest number of abstract submissions to date, a testament to the growing urgency and creativity with which our global community is responding to these challenges. I extend my sincere gratitude to the Review Committee, whose expertise spans policymakers, academics, and industry experts. Their thoughtful engagement and critical insight have been instrumental in curating and shaping the quality and depth of this document.

The papers presented here reflect a profound shift in our discipline. They reveal design not as a product of industry alone, but as an evolving philosophy of co-existence, responsibility and renewal. Across disciplines and geographies, a shared narrative emerges: Design for Planet is no longer an aspiration but a necessity.

The papers explore how creative education and professional practice can embed circularity, reuse, and regeneration as foundational principles. They invite us to reconsider value itself, moving from extraction toward reciprocity, from innovation as growth to innovation as care.

Equally striking are the works that foreground human plurality, embedding citizens, communities, and neurodiverse perspectives within the transition to green and circular economies. In these examples, inclusivity is not a gesture of access but a condition of insight; diverse ways of thinking and perceiving become essential to designing resilient, adaptive futures.

Many of this year's contributions also exemplify how design thrives through collaboration, between universities and industries, researchers and practitioners, technology and craft. This interdependence signals a maturing discipline that learns not in isolation but through networks of shared responsibility.

Taken together, these papers chart the movement of design from object-making to world-making. They remind us that design's true material is not the artefact, but the relationship, between people, planet, and possibility. To design now is to participate consciously in the making of futures that are equitable, imaginative, and enduring.

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THEME 1

Shifting Paradigms — From Extractive to Regenerative Design

Design is at a pivotal moment where its role must transcend sustainability and embrace regeneration. This theme explores the paradigm shift required to design systems, products and spaces that not only reduce harm but actively restore and renew ecosystems. It delves into the principles of regenerative design, including biomimicry, systems thinking and circularity.

Appropriate Technologies: For Regenerative Practices and Ecological Citizenship, Yielding Planet-centred Design

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Abstract

This article examines how technologies could be reimagined not as instruments of extraction or control, but as entangled agents within ecological, social and infrastructural systems, capable of facilitating Ecological Citizenship. Authors critically analyze contemporary design-led technologies, illustrating a paradigmatic transition from extractive practices to regenerative methodologies. This work builds on a review of extant literature across disciplines of design, philosophy, cultural criticism and science, exemplified by a discussion of Ecological Citizenship technologies in practice. Examples span established case studies, pilot projects funded by the EPSRC (UKRI funding body), the broader domains of commercial production, academic research, ecological science and distributed local communities.

Rather than treating the ecological and technological as opposing forces, authors elaborate an integrated account of their entanglement towards the development of a methodology for designers, technologists, and citizens to engage with planetary futures through participatory, situated, and contextually appropriate practices. This review culminates in the *Ecological Citizenship Technologies Framework (ECT Framework)*, a conceptual tool for the analysis, design and distribution of technologies within an ecologically interdependent planetary context.

Keywords: Design with nature, ecological citizenship, more-than-human design, planetary conviviality, planetary infrastructure, reciprocal technologies, regenerative technology.

Introduction

The following discourse is situated within an integrated field of design, technology, and Ecological Citizenship, addressing audiences across design practice(s), design research, ecological practice and civic governance who recognize that technological infrastructures are ontologically inseparable from the ecological systems in which they operate. Its applicability lies outside the prescription of reductionistic solutions (Vian et al. 2023), proposing a mode of enquiry that recasts technology as an existential condition of planetary life, a constitutive force that coproduces ecological and civic realities on a planetary scale. This research scope pertains to designers, technologists, citizen activists, policymakers, and ecologically oriented practitioners seeking paradigms adequate to the demands of regenerative planetary action.

Authors primarily interrogate how technologies can be understood as infrastructures of Ecological Citizenship: how they might catalyze agency and autonomy without reproducing atomization, enact reciprocity without reverting to nostalgic naturalism, and remain responsive to emergent ecological conditions without collapsing into more facile implementations of techno-solutionist prescription (Sætra & Selinger 2024). The argument insists on a reconfiguration of technology as necessarily intrinsic with ecological processes, refusing the entrenched epistemological binaries that have historically positioned nature as passive substrate and technology as active agent (Alves et al. 2024). But this is not merely a move to mediation between pre-existing agents; technologies also produce an image of the world they interpenetrate, especially where sensors and climatic visualizations render long-term planetary phenomena, such as warming trends or land cover shifts, visible in ways human perception alone never could. Remote sensing systems, for instance, do not just transmit data: they mediate an Earth-image that shapes political imaginaries (Voordijk et al. 2024).

Ecological Citizenship Technologies (ECT) are therefore intrinsic within ecological processes, and their value supersedes efficiency as its sole measure. They are evaluated more by a capacity to negotiate ecosystemic interdependence and planetary conviviality: a condition in which technologies are designed and governed as relational agents which cultivate mutuality across human and more-than-human systems. This extends Illich's notion of convivial tools (Illich 2009) from the domain of human autonomy to the planetary scale of ecological interdependence. The article proceeds by tracing the conceptual genealogy of Ecological Citizenship technologies. This trajectory is extended through planetary design discourses (Akama et al. 2020), ecological epistemologies (Scheiner et al. 1993), and analyzes that understand technologies as instrumental, material artefacts as well as vehicles of existential change. Authors position ecological design as a mode of planetary practice, in which technological mediation is inseparable from the production of ecological knowledge and the expanded conditions of citizenship itself.

This orientation is demonstrated in implementations through which participatory biodiversity platforms such as eBird (Peterson et al. 2025) convert distributed observations into planetary governance data and position citizens as active epistemic agents of change. It is exemplified in community-based water monitoring projects where Indigenous practices conjoin with institutional systems, producing a polycentric citizenship that is both local, distributed and systemic (Rathwell, Armitage, & Berkes 2015). It is also notable in the work of environmental justice sensor networks in the *West Oakland Environmental Indicators Project* (West Oakland Environmental Indicators Project, n.d.), where the civic standing of residents is juridically transformed through the evidentiary force of community-deployed monitors (Sabin Center for Climate Change Law 2025). Taken together, these practices position citizenship not as a prescriptive category but as a technologically mediated condition, coincident with the very processes of ecological design and planetary conviviality they sustain. We summarize this perspective as: ***Sustainable Intentions >*** *The proposal initiation and intent is to build sustainable practices.*

Case studies, ranging from UKRI-funded pilot projects to international initiatives, function less as exemplars than as probes: they indicate the possibility of technologies that are non-extractive, designed in collaboration, catalytic of agency and autonomy, and contextually adaptive. The importance of these examples lies not in the instrumental objective of their outcomes but in their generativity: each demonstrates how Ecological Citizenship can be materially instantiated in technological form. Though the work is grounded in a UK perspective, (given the conditions of UKRI support), the articulated framework yields transferability. The ecological entanglements described do not recognize national borders, and the epistemological orientation advocates reciprocity and an intersystemic awareness that is inherently multiscalar and planetary.

Authors build from a set of interlocking precedents: ecological design traditions attentive to context and relation; epistemologies of ecology that prioritize entanglement and interdependence, theories of technology that recognize its existential force, and discourses of Ecological Citizenship that transfer responsibility from atomized consumers to distributed collectives across human and more-than-human domains. It is from this nexus that authors specify a framework, not as a rigid schema, but as a generative scaffold – an invitation to imagine technologies that are not simply instruments for human ends but existential conditions of ecological reciprocity.

For example, the Khasi and Jaintia peoples of Meghalaya (India), cultivate *Living Root Bridges* by guiding aerial roots of *Ficus Elastica* across streams and ravines. Over centuries, these bridges strengthen as roots thicken and interweave; a bridge is not constructed in a single cycle of design and deployment but lives, grows, and adapts with the local ecosystem across connected scales of time. These structures provide a connectivity of human flow while also contributing to slope stabilization, biodiversity corridors, and flood resilience (Ludwig et al. 2019).

This case demonstrates a technology that situates human ends as intrinsically connected to ecosystems and Ecological Citizenship: the root-bridge is a co-constructed human infrastructure that emerges in reciprocity with ecological growth. The *Living Root Bridge* constitutes an existential condition of ecological reciprocity by connecting human access, plant growth, hydrological cycles, and habitat support into a living infrastructural assemblage.

This case also suggests that the sole analytical axis of Ecological Citizenship Technologies cannot be reduced to 'low' vs 'high' technologies and exists as a constellation of values across more-than-human spans of time, capacities for repair, the promotion of regenerative growth, strategies conscious of decay, and the ethos of intersystemic cohesion. We summarize these insights as: ***Accessible >*** *Easy entry point(s), low friction interventions, could be inter-generational, considering its life over time.*

In this sense, the contribution of this article is to reformulate conventional understandings of technology itself: from an instrumental artefact to a planetary practice, a distributed epistemic agent through which ecological and civic futures are continuously negotiated. By repositioning design within the larger context of planetary kinship, by associating technology with reciprocity, and by understanding citizenship as inherently ecologically entangled, authors promote a discourse in which preferable futures may be enacted as processes of relational intersystemic coproduction across innately connected planetary spheres.

We position ourselves regarding the use of the term 'Appropriate Technology' in line with contemporary strands of extant discourses surrounding it that extend its anthropocentric roots (Tufarelli 2025). As this concept has conventionally focused on technologies tailored to human scale, social equity, and localised forms of empowerment (Bishop 2021; Clegg 1988), we endorse an interpretation that broadens this scope to include ecological systems and more-than-human forms of inclusion. From this perspective, technologies are 'appropriate' both when they meet human needs sustainably and when they cultivate reciprocal relations across environmental domains and multispecies

ecologies. They are appropriate to their circumstances, duration, impact and are not shoehorned into conventional frames of high, or low...but suit their environment of delivery. For example, a nail chosen for timber frame construction over a screw, as it enables the building to move, is more durable and is cheaper.

Prevailing perceptions often depict technology as inherently oppositional to ecological sensibilities and behaviours. This perspective overlooks the entangled co-emergence of technological and ecological systems (Rakova et al. 2023). Challenging this binary opposition, our examination seeks a perspectival reorientation towards technology as integrated within Ecological Citizenship, suggesting a new mode of technological praxis embedded in its ecological and social contexts. This reorientation is further developed and articulated through specific design tools and principles, exemplified by case studies indicating preferable future trajectories for technology creation, deployment, and governance. By embedding regenerative principles into technological praxis, authors advocate a turn from anthropocentric operational efficiency to mutualistic planetary existence. Project signposting includes:

1. **The Citizens Air Complaint Programme**: incentivizing communities to actively report idling vehicles contributing negatively to local air quality.
2. **GainForest**: decentralized non-profit organization leveraging archival analytical methodologies for earth's ecological data, reinforcing transparent and inclusive environmental decision-making.
3. **AgLab**: enabling farms to produce low-carbon, plant-based insulation blocks using existing agricultural waste materials and equipment.
4. **Ecology of Things**: regenerative approaches to ecological-technological integration.

Central to these case studies are design principles characterized as:

1. Non-extractive
2. Created in collaboration not others
3. Designing for future ownership, governance and design for exit
4. Produced in considerate to its surroundings as is appropriate tech, not merely high tech

Ecological Citizenship

For the purposes of this article, Ecological Citizenship is understood as a mode of relational participation that converges across ecological, technological, and social fields. Initiatives such as the EPSRC-funded *Ecological Citizens(s) Network+* exemplify this approach – mobilizing communities of knowledge and practice that integrate environmental knowledge with civic agency. *Ecological Citizen(s) Network+* project EcoLandS equips communities with a digital platform to identify, claim, and collaboratively manage disused land for autonomous approaches to urban biodiversity, suggesting a more inclusive model of land governance in which communities, ecologies, and technological practices collectively organize local space in ways that shape and sustain emergent forms of Ecological Citizenship.

Given that broader discussions of citizenship as a function of sovereignty and state are outside the scope of this article, our use of the term resists narrow legal-or state-based definitions that confine citizenship to a framework of legislated rights and privileges. Instead, we draw on a more expansive and situated understanding, where citizenship is distributed across all living entities that participate in, and are affected by, the ecological and social dynamics of a place. This view resonates with Latour's proposition of a *Parliament of Things*, where more-than-human entities are recognized as active participants in shared worlds (Latour 2004).

Citizenship is thereby understood as a relational stake within a shared environment, an orientation that extends beyond the human to acknowledge multispecies and multisystem, multiscale interdependence (Donaldson & Kymlicka 2011; Dunkley 2023; Kymlicka & Donaldson 2014; Rupprecht et al. 2020). This form of citizenship is not exclusive but entangled: it exists across domains of human intentions, ecological processes, and technological mediation, redefining agency as collective, mutualistic, polycentric and distributed. As such, Ecological Citizenship implies a responsibility to more-than-human systems, situating ethical agency within ecological interdependence rather than juridical entitlement. This move reconfigures citizenship from a tiered package of negotiable rights into a set of duties rooted in and emerging from planetary kinship, reciprocity, and relational accountability.

We propose that Ecological Citizenship should not be an anthropocentric endeavor, and that this necessary feature represents a meaningful distinction from conventional categories of citizenship. Current discourses still often reflect the reproduction of 'human values', as with the discussion surrounding 'AI alignment' (Ji et al. 2023). As critics observe, AI alignment as conventionally conceived assumes the centrality of human preference and instrumental rationality, often suppressing more-than-human interests and ecological complexity. For example, Tan et al. (2024) critique prevailing 'preferentist' alignment frameworks that treat human preferences as the sole axis of AI ethics, ignoring value pluralism or ecological contexts (Zhi-Xuan et al. 2024). Korecki (2024) introduces the concept of *Biospheric AI*, arguing that an anthropocentric model of AI 'alignment' is insufficient and risks systemic harm by marginalizing biospheric concerns. A broader scoping review of AI ethics standards finds that anthropocentrism frequently marginalizes more-than-human animals and environmental well-being (Rigley et al. 2023). With this in mind, a focus on more-than-human ecologies and their entanglements across spheres of analysis (biosphere, technosphere) contextualizes our discussion of Ecological Citizenship as it pertains to discourses around anthropic decentring and its potential for the restructuring of technological praxis.

Phillips et al. (2023) describe Ecological Citizenship as comprising 'accessible activities and skills which establish sustainable practice(s) and/or address ecological inequalities,' emphasizing duties to ecosystems and communities over individual liberties. Spannring (2019) argues that Ecological Citizenship calls for a reorientation towards more-than-human domains, embedding strong relational obligations into civic identity. A parallel emerges in recent participatory design projects that elevate more-than-human stakeholders through ecological obligations. In one urban biodiversity initiative, designers developed a 'participatory ladder for non-humans,' inviting bees and plants into the design decision-making loop with tangible rights alongside human participants (Hernandez-Santin et al. 2023). This exemplifies a duty-based citizenship: humans are morally and materially obliged to shape environments in ways that sustain multispecies communities, not merely preserve human instrumental prerogatives. We also highlight the difference between 'participation' and 'engagement' where citizens are able to be actively involved in the work, moving into post-participatory modalities (Phillips & Ferrarello 2025).

This duty-oriented stance challenges conventional rights-based frameworks, where eviction of a species from an urban site might be legal but unethical within an Ecological Citizenship discourse. It compels designers to recognize and enact obligations toward nonhumans, making ecological accountability inextricable from design praxis. Ecological Citizenship extends normative environmentalism by prioritizing relational agency and multispecies responsibility within sociotechnical systems. As designers, we situate our practices within these systems, aiming not just to solve discrete problems but to reconfigure the relational ecologies that connect communities, technologies, and environments (Bauer & Herder 2009; Norman & Stappers 2015).

Authors question how technologies might be designed, distributed, deployed and governed to mitigate harm and actively support regenerative futures; what design principles (Raymond et al. 2025), epistemologies (Toner et al. 2023), and engagements (Richardson et al. 2016) could guide this reorientation? Ecological Citizenship concerns environmentally responsible behaviours individually and collectively, with an eye towards the reorientation of political and technological subjectivity, wherein citizenship is distributed across species boundaries, ecological systems, and infrastructural entanglements, affirming collective responsibility, interdependence, and relational agency within a mutually constituted planetary context. Ecological Citizenship offers a reorientation of agency that neither collapses responsibility into the atomized figure of the 'responsible consumer' nor abandons the possibility of effective action. It displaces the rhetorical burden of planetary repair from the individual as a self-regulating unit towards the individual as situated within ecological and infrastructural systems. In this sense, Ecological Citizenship invites modes of design that cultivate autonomy without reproducing the isolating logics of behavioural nudging (Schmidt & Engelen 2020) or reductive techno-solutionism (Jensen et al. 2021; Sætra & Selinger 2024). Projects like *GainForest* (Dao et al. 2019), which reconfigure data infrastructures as collectively governed ecological commons, or *AgLab* (LeadsOnTrees 2024), where the ecology of material cycles are redirected through localized agricultural knowledge, exemplify a recalibration of agency that is distributive, regenerative, and collaborative.

Conversely, carbon-footprint calculators and personal-offsetting apps, regardless of their theatre of empowerment, reinscribe the fantasy of sovereign individual action, presenting planetary-scale disruption as a ledger of lifestyle choices. Bird identification apps enable new sensory relationships with ecological domains, yet they risk incentivizing ecologically disruptive attention, collapsing ecological presence into gamified capture (Lundquist et al. 2025; Peterson et al. 2025b); this concern connects with broader critiques around the ethics of gamification that have pertinence to principles of Ecological Citizenship, particularly the potential for inhibition of autonomy (Klock et al. 2023).

The challenge for designers, then, is to engage with technology not as a neutral intermediary but as a constitutive force within interdependent planetary systems in ways that illuminate systemic entanglement, refuse moral outsourcing, and generate conditions for a collective reconstruction of technological praxis, with the aim of ensuring that communities can access it and have autonomy though it, and if necessary, from it. In this sense, the mutualistic production, deployment and use of a technology in context and the conditions it enables becomes a cooperative act of citizenship in itself. We summarize these perspectives as: ***Designed 'with, not for' >*** *Designed with people, openly in collaboration, not inflicted upon them.*

The Ecological Citizen(s) Technology Framework

The *ECT Framework* functions less as a rigid model than as a generative scaffold, capable of informing design, governance, and technological imagination. Its affordances lie in its openness: enabling iterative, participatory, and ecologically embedded engagements. Post-participatory design gives citizen(s) agency to manoeuvre and dictate outcomes rather than just 'attending' in another's vision of a proposition (Phillips & Ferrarello 2025) . It means that the work is edited at source and can enable new conversations, for citizens with citizens. Whether through prototyping speculative ventures or analyzing existing interventions, this toolkit repositions the locus of technological agency from extraction to relation, from optimization to planetary kinship.

This framework is deliberately open, scalable across contexts and disciplines. It functions not as a static schema but as a responsive interface for ecological engagement. Its main affordance is to render visible the relational and systemic dimensions of design, prompting reconsideration of assumptions about efficiency, neutrality, and agency. Proposals should be understood not as solutions but as enabling care, adaptation, and reciprocity. Designing for openness allows ecological and social systems to evolve alongside technologies.

Design prototypes should be understood as probes: they do not predict the future, but test, inform, and enable others to collaboratively shape it over diverse scales of time and connected systems. Any codified set of design principles cannot completely eliminate harm or failure. Its strength lies in its humility: by prioritizing process over product, relation over control, it enables more responsive and ethical engagements. Its value lies not in productivity or scalability but in its capacity to promote situated agency, deepen ecological literacy, and reorient design as a planetary practice. Prototyping must also take into consideration that planetary scale design often does not scale from the local experimentation; complexity science and systems theory reflect this, when large-scale aggregates act differently to the sum of their systemic components (Yuan et al. 2024). Local experiments often fail to generalize as systems aggregate and new cross-scale feedbacks emerge (Braithwaite et al. 2018). Rather than assuming that prototypes will smoothly expand, the design process must embed reflexivity when local dynamics fail to generalize, so the system can reconfigure, decentre default assumptions, and reorient modes of design practice. To 'think like a gardener, not a watchmaker' (INCOSE Complex Systems Working Group 2015) is a helpful conceptual directive to guide this perspectival shift.

By using the *ECT Framework*, designers and citizens may reorient their tools toward ecological attunement, contextual adaptation, and ecosystemic coexistence. Authors propose using the toolkit to imagine speculative technologies that are plausible but existential: grounded in ecological realities and suggesting more expansive social contracts. Amid accelerating ecological degradation (Huesemann & Huesemann 2007) and increasing technological ubiquity (Donges et al. 2017), the need to reconfigure our relationship with both is urgent (Fletcher et al. 2024) and inherently interdependent (Krueger et al. 2022). The complexity of contemporary technologies demands more than instrumental thinking: it requires systemic, ecological understanding. For example, *Resting Reef*, a UK-based initiative that uses cremated human or pet ashes as material to construct bio-receptive reef structures. These submerged memorial reefs create habitats and considerably increase marine biodiversity, simultaneously functioning as carbon sinks and coastal resilience infrastructure. *Resting Reef* (Resting Reef, n.d.) distributes infrastructure as ecologically generative, directly embedding the sociotechnological within living ecological systems. This kind of thinking demonstrates how the *ECT Framework* can move from conception to practice, specifying technologies that respond to ecology while simultaneously reconfiguring citizenship as a coextensive relation between social contracts, material infrastructures, and living systems. We summarize these perspectives as: ***Stewardship / Considers End of life >*** *Proposition considers its end of life, its subsequent stewardship.*

What is an Ecological Citizen(s) Technology?

Ecological Citizen(s) Technologies (UKRI n.d.) deviate from the instrumental view of technologies as artefacts or products; they are processes, practices, knowledge systems and infrastructures (Kline 1985) that embed regenerative intent, catalyze autonomy, and afford relational entanglement between human and nonhuman ecologies. Technology, in this understanding, is a mode of existence within interdependent, overlapping systems (Breitschopf et al. 2023). Technology is situated, participatory, and multiscalar, capable of shaping values, ecosystems, identities, and interspecies relations (Gooding et al. 2025). We propose a vision of design that is aware of its location within a complex fabric of ecological dependencies, tensions, and precarious equilibria. From that awareness follows the multiscalar and temporal orientation of this work: design must be assessed for its effects on humans as well as being situated across ecological niches, across variable scales of time and space. For example, anthropogenic noise interference has been shown to mask critical communication signals, disrupt mating or territorial calls, and reduce hatching success *in* bird populations (Sieving et al. 2024), effects that compound over time and across species. Moreover, chronic noise pollution can restructure biological communities, altering species interactions in ways that persist even after the noise is removed (Senzaki et al. 2020). What seems benign at one scale or moment can, when aggregated and extended temporally, fracture ecological homeostasis and reconfigure system dynamics (Falk et al. 2019).

Ecological Citizen(s) Technologies are those that enable non-extractive, post-participatory (Phillips & Ferrarello 2025), and context-sensitive practices. They are not deployed upon systems, rather they are convergent with them, connecting technological agency with ecological resilience and multispecies interdependence. Distributed sensing infrastructures governed by local communities, or regenerative material systems rooted in Indigenous ecological knowledge, demonstrate this conceptual expansion of technological production. In their comprehensive review of environmental monitoring initiatives, Thompson et al. (2020) found that where Indigenous communities hold greater decision-making power, monitoring programmes diverge in objectives, indicators, and management strategies compared to externally driven models, leading to more contextually attuned ecological outcomes. In many examples, Indigenous participants introduced locally salient indicators that had previously been ignored, reshaping the definition and practice of environmental monitoring; local observers recalibrate assumptions about water dynamics, repositioning technology as a mediator of situated water knowledge. In the Yukon River Basin, Indigenous knowledge from Ruby Village has revealed observations often absent from scientific hydrology, that are critically informative when paired with extant scientific knowledge (Wilson et al. 2015). The Ecological Citizen(s) approach to technology understands the relationship between citizenship and technology as a form of activity produced by people and more-than-human actors; *Ecological Citizen(s) Technologies* are always modes of action insofar as citizenship is enacted through their use and production in practice (Voinea 2017).

For example, *Public Lab's* community-driven air quality monitoring networks enable local residents to build, deploy, and interpret low-cost sensors in collaboration with regional groups, integrating data production with local environmental experience and civic regulation (Rey-Mazón et al. 2018). Another project, *Blue Ceramics*, developed through participatory co-design between marine ecologists and local communities, produces morphing ceramic substrates to restore seagrass meadows by integrating ecological knowledge and iterative material experimentation (Arredondo et al. 2022). These instances illustrate how Ecological Citizenship-informed technological praxis can emerge from place-based ecological knowledge, coordinating design systems with situated experience and ecological process rather than external solutionist imposition. These strategies position technology not as a neutral instrument but a medium through which ecological process, civic organization, and design experimentation are understood as intrinsically associated features; their design and implementation enacts Ecological Citizenship, a conjunction of human and ecological domains that constitutes planetary technological praxis. We summarize this oversight narrative as: ***Benefits wider communities/each other >*** *Through its actions others benefit, like planting flowers, pollinators benefit, as do allotment owners.*

Nature and Technology

The orientation of nature and technology as oppositional domains (Horáková 2017; Uggla 2010) is a persistent cultural position. Deconstructing this dichotomy of 'inert' nature contrasted with 'active' technology, authors propose a more entangled view that sees both as co-productive elements of ecological systems and their planetary context (Ahlborg et al. 2019; Chester et al. 2023). Dominant narratives often position nature as a static backdrop and technology as the active force shaping it; an epistemological bias (Etuk & Inwang 2024; Trächtler 2024) that reproduces hierarchies of control and extraction. Authors challenge this dualism by prioritizing agency, proposing instead that both nature and technology are active participants in shaping emergent systems. Within this view, technologies are not neutral tools but active, multi-domain, productive systems in themselves. Authors reject the presumed notion that nature is a passive resource, and technology an active force of production. Instead, authors understand both as interpenetrating and co-determined, operating through mutual adaptation and exchange. In practice, this orients design beyond artefacts toward the reconfiguration of practices and institutions, and it treats success as the degree to which arrangements enable situated autonomy and convivial use (Voinea 2017b) rather than sole dependence on centralized actors. This correlates with systems thinking in design for social innovation (Donges et al. 2017), transitions research on ecological regime shifts (Sardanyés et al. 2024), and convivial tools that maximize user and community autonomy without excluding systemic approaches (Voinea 2017).

These rhetorically persistent oppositions (Luque-Ayala et al. 2024; Vidal et al. 2024) function as epistemological shortcuts that produce design outcomes discordant with the complexity of ecological systems. When technology is presumed to be inherently extractive and nature inherently virtuous, interventions are structured around false binaries rather than systemic understanding. The consequences are evident in both policy and practice: carbon offset schemes reliant on monocultural plantations (Bosselmann et al. 2024) mimic ecological form without ecological function, resulting in fragile, non-resilient systems that degrade biodiversity under the guise of naturalism (Cheong 2025). At the same time, so-called artificial interventions, such as coral reef restorations constructed from repurposed urban materials or waste substrates, often outperform their 'natural' counterparts in terms of biodiversity and resilience. This reveals that the problem is not artificiality per se, but a lack of systems literacy in design thinking. Technologies do not emerge outside of ecological conditions; they are always already present within them. In the domain of policy and governance, relevant scholarship around Social-Ecological-Technological Systems (SETS) conceives of urban or planetary contexts as inherently hybrid assemblages where infrastructures, ecological processes, and social practices are entangled (McPhearson et al. 2022). For designers, this recognition repositions the focus towards material and procedural entanglements that structure everyday life; objects, infrastructures, and behaviours intrinsic to ecological and technological processes. Rather than relying on performative gestures toward 'nature', it calls for practices that situate design within the negotiation between ecological, social and technological systems.

Natural is not enough. Counterproductive modes of anthropocentrism ingrained in well-intended thinking around categorizations of the natural in opposition to artificiality can counterintuitively reiterate notions of otherness that cast the human as radically disconnected from ecological domains. One such critique (Cronon 1996) sees that this culturally embedded opposition "... embodies a dualistic vision in which the human is entirely outside the natural", and as such reproduces instrumentalist conceptions at the core of contemporary attitudes to the ecological. Even in agricultural systems marketed as 'organic,' ecological risk persists. In one study, (Bahlai et al. 2010) found that two organic pesticide formulations caused higher mortality among beneficial insects than two of four tested synthetic alternatives, frustrating the common assumption that 'organic = benign.' This case underscores that what matters is not reductive categorizations but design fluidity: selectivity, persistence, target specificity, and deployment context. By rejecting the moral shorthand of 'natural = good', a discourse for mobile and ecologically entangled modes of technological authorship is enabled, in which design learns from ecological processes without reductively idealizing them, and in which technology is recast as a situated practice embedded within living systems (Giaccardi et al. 2024).

PhotoSynthetica, developed by *ecoLogicStudio*, demonstrates an effective negotiation of this discourse in action. The project recasts building façades as living systems by embedding microalgae bioreactors within ETFE cladding modules. These bioreactors capture carbon dioxide and pollutants from the air, convert them into algal biomass using solar energy, and release oxygen back into the built environment (PhotoSynthetica, n.d.). The operation of the system demonstrates active participation in urban metabolism, leveraging living processes to reduce energy consumption and improve air quality. (Sedighi et al. 2023). *PhotoSynthetica* engages ecological metabolism directly rather than merely mimicking natural appearances, positioning infrastructure as a living eco-technical agent within its environment. We summarize this overview as: ***Intent on Autonomy >*** *The proposition yields autonomy with citizen(s) not solely reliant on governmental powers.*

Existential vs. Instrumental Technologies

Authors' analysis finds support in theories which distinguish between instrumental and existential technologies (Antikythera n.d.): technologies that reconfigure our perceptions, values, and identities contrasted with those which solely engender specific, quantifiable ends. Instrumental technologies afford efficiency and control; existential technologies reconfigure relational structures, collective values, cultural understandings and perceptual frameworks. *Ecological Citizenship Technologies* understand technology in its existential dimension, without rejecting utility and accessibility as guiding principles.

Technology in this understanding is treated not simply as applied science or engineered artefact, but as a way of knowing and shaping the world; multi-domain, distributed epistemological agents. Existential technologies reconfigure perception and subjectivity, making them integral to ecological learning and adaptation. Rather than understanding technology as the production of tools with fixed purposes in singular problem-domains. Using the notion of existential technology as a design provocation, authors advocate for practices that understand technology as always already embedded within its constitutive material networks; technology as intersystemic, ecological, planetary.

This positioning conceives of technologies as relational and distributed, their logic in confluence with more-than-human ecologies. They do not simply accommodate more-than-human life but arise from dialogical processes that include it (Livio et al. 2022; Oktay et al. 2023). Some projects that embody this ethos:

Augmented Nature: This AR prototype enables residents to visualize and design micro-scale greening interventions in underutilized urban spaces, recontextualizing planting as a sensorial technology, reshaping perception, spatial awareness, and communal ecological imagination. By merging immersive design with ecological feedback, the project reconfigures how people see and act within urban ecologies (Royal College of Art, 2025), AR tools in *Augmented Nature* alter how urban nature is perceived.

Beyond the Colony: This multidisciplinary project positions social insect colonies as collaborators to explore emergent ecological logics and enable multispecies creative collaboration. The technology becomes a platform for distributing agency, restructuring the relationship between human and more-than-human systems. Avoiding predefined outcomes, the process examines how communities relate to ecological agency (Royal College of Art 2025), reshaping how we understand more-than-human intelligence.

Community Energy Citizen Science: Under the *CE-CS* project, local fishers' knowledge is constructed into a real-time water quality monitoring framework, embedding communities and ecologies within the design process. This initiative presents data infrastructure not as a centralized system, but as an *ecological commons*, where technology converges with place-based governance, evolving perceptions of environmental care and collective agency (Stockholm Environment Institute n.d.). *CE-CS* facilitates the coproduction of environmental knowledge and governance structures, developing technological infrastructures that grow from ecological relationships. We summarize this overview as: ***Planet/Natural World Benefit(s) >*** *Deep consideration to the surrounding environment*.

It is also true that the expansive reconfiguration that mass-scale sociotechnological interventions induce have the potential to marginalize communities, reinforce inequalities and bolster hegemonies as much as they might simultaneously liberate and deconstruct others. Ecological impacts of existentially transformative technologies have been widely observed and objectively measured. Scaling AI, for example, expands electricity demand and freshwater withdrawals; model training and inference carry measurable carbon and water footprints, and data centres place additional stress on local basins and grids (Li et al. 2023; Zewe 2025). Electronic waste is rising faster than formal recycling capacity, with most devices not recovered or safely processed (Lee et al. 2017; International Telecommunication Union 2024). Upstream, the minerals that underwrite electrified infrastructures intersect with high-risk social and ecological contexts, with documented land disturbance and biodiversity pressures (Owen et al. 2022). Efficiency gains in digital systems are frequently absorbed by rebound dynamics when they lead to increased usage and consumption, so aggregate burdens persist even as individual devices become more efficient (Freitag et al. 2021; Widdicks et al. 2023).

Planetary-scale computational infrastructures may tend towards the consolidation of geopolitical power and magnify inequalities and even as they claim to democratize planetary knowledge (Crawford 2022; Wu et al. 2022). When conventionally established forms of knowledge production are reordered, resultant structural reinforcement can engender epistemic displacement; by reshaping our modes of knowing, such technologies can marginalize alternative or traditional epistemologies. As Hopster (2024) explains, disruptive technologies can create 'conceptual gaps' that marginalize established interpretive frameworks and deepen epistemic exclusion (Noble 2018). For example, in AI language systems there is often techno-linguistic bias: the system privileges certain linguistic and cultural frameworks and is unable to represent concepts from marginalized languages or worldviews. This creates conceptual gaps: speakers of minority or non-dominant languages find that the system cannot translate or express their concepts, marginalizing their epistemic domain (Helm et al. 2023).

Technological interventions that radically reorient perceptual understandings have the potential to contribute to the loss of human agency, submitting decision-making authority to algorithmic logics; as technology transforms collective perception, it cedes human and more-than-human autonomy to digital authorities that interpenetrate global systems attendant to earthly life (Mitelut et al. 2023). In Antikythera's discussion of sociotechnical disruption, Bratton applies the notion of the Copernican trauma to describe the cultural fragmentation initiated in the contemporary emergence of artificial intelligence; technologies which radically transform human self-understanding have the capacity to destabilize as much as they illuminate, and in fact suggest paradigms beyond entrenched techno-utopian and technopessimistic ideological rhetoric (Nørgård & Holflod 2024), often embedded in anthropocentric positions (Bratton 2024); existential sociotechnical transformation necessitates neither broadly utopian nor terminally apocalyptic outcomes (Ng & Lin 2024; Sand 2024).

Biomimicries

The authors' approach to biomimicry again illustrates this contrast (Mathews 2011). Instrumental applications of biomimicry treat nature as a reservoir of solutions; an Ecological Citizen(s) approach to biomimicry understands ecosystems as partners in interdependent co-evolution (Blok 2022; Hayes et al. 2019). Authors understand Ecological Citizenship technologies in the context of biomimicry as ecosystemic (Blanco et al. 2021), embedded (Flora Robotica, n.d.), and generative (Dixit & Stefańska 2022).

The premise that waste does not exist in nature, as articulated by cradle-to-cradle thinking McDonough and Braungart (2009), illustrates the imperative to design for circularity not in mimicry of surface features, but in consonance with the underlying logics of ecological metabolism (Brown et al. 2004). Biomimicry (Fisch 2017), when reduced to the imitation of individual organisms or aesthetic forms, risks perpetuating anthropocentric modes. Biomimicry at the level of systems (Lebdioui 2022), such as nutrient cycling (Balbinot et al. 2024), mutualistic infrastructures and adaptive feedback enable a generative reorientation with the potential to reposition the process of design towards a mode of ecological mutualism, where the role of the designer is not to impose form upon a passive substrate, but to participate in the unfolding of systemic relationships, attuned to patterns of interdependence, temporality, and more-than-human agency.

One illustration of this thinking around mutualistic ecosystemic biomimicry is the *Living Breakwaters* project by SCAPE (SCAPE Studio, n.d.) in Staten Island, New York. Alongside extant research into 'living shoreline' approaches to coastal restoration (Scyphers et al. 2011), the project sees a chain of limestone and ecologically-modeled textured concrete breakwaters seeded with live oysters; over time the reef structures attenuate storm waves, trap sediment, and grow their own habitat, turning coastal defense into a living metabolic process. This inherent bio-receptivity positions autonomy as more-than-human, decentring anthropic goals without the presumption that this requires abandoning human needs; a distributed, fluid and inclusive priority structure emerges in its place. Rather than extracting a set of features from nature, the design integrates surrounding ocean ecology to bolster shoreline resilience, marine biodiversity and positive systemic interdependence yielding an embedded, generative technology that adaptively constructs itself as ecological conditions change.

Multistability as Design Practice

Technological approaches to Ecological Citizenship must consider multistability: the potential for technologies to assume multiple, context-dependent meanings and uses (Whyte 2015). The use-in-context of a technology over time often exhibits fluidities according to evolving material contingencies. The potential mutability of technology 'in the wild' can engender changes in existing orders of socio-technical relations, or restrict and reinforce them (Shanahan et al. 2024); this means monostable solutionist design approaches must adapt to contend with a potentially fluid array of *in-situ* use cases, with sometimes simultaneously emergent and contradictory cross-purposes (O'Neill 2018). Recognizing the multistable potential of technology allows for the development of approaches that cultivate an ethos of responsiveness over determinism as a positional variation in the design and production of technologies.

One example exists in the emerging space of 'community-mapping' (Parker 2006), especially in its use of drone technology: community-based drone usage in West Kalimantan, Indonesia, demonstrates how drones mutate the sociotechnical dynamics of technological deployment and production. Initially introduced as tools for 'counter-mapping' (Ruzol & Dayrit 2023) to help local communities document forest encroachment and claim land rights, drones quickly acquired local meanings. Citizens repurposed them to monitor river pollution, trace seed dispersal zones, and support intercommunity ecological dialogues (Radjawali 2015).

Beyond the planned scope of their deployment, drones reshaped power relations by transferring authority from external NGOs and state actors towards locally situated, community-led data governance. Yet in some instances, drone ownership and flight privileges were consolidated by regional elites, reinforcing local hierarchies and limiting access. This simultaneous expansion of agency and the reinforcement of inequality exemplifies the multistable mechanics of technological distribution: what emerges in-use often diverges from design intent, revealing how context and control mediate their ecological and sociotechnical impacts.

Given the possibility for deployed technological interventions to produce both novel relational ecologies and reified inequalities, it becomes imperative for design frameworks to anticipate and adapt to emergent, contradictory use patterns, anticipating multistability, uneven agency, and transitioning regimes of control.

Kinect: Multistability in Action

Originally released by Microsoft in 2010 as a consumer gaming peripheral, built on *PrimeSense* (Wong, n.d.) depth-sensing technology, *Kinect* was designed to track bodies in living rooms for interactive gaming development; it very quickly deviated from this intended domain. Artists and interaction designers adopted it for interactive environments and embodied perception (Bowen, n.d.; Stinson 2015; Sorci 2018); scientists reoriented it toward environmental sensing and measurement (Pagliari & Pinto 2015) (Azzari et al. 2013). Diverse communities of practice emerged around *Kinect*, and open software interfaces were developed and shared by practitioners themselves to support them (OpenKinect, n.d.).

This history exemplifies the idea of technological multistability as an unfolding in-the-wild process. A single artefact acquires different meanings and practices as it immigrates from living room to lab to riverbank and gallery; its meaning is not exhausted by its structural features, but by the affordances and behaviours it enables. The *Kinect* functions as an Ecological Citizenship technology when it is situated with communities as a low-barrier sensor that supports autonomous action: quick vegetation scans to evidence habitat change, stream-surface measurements to advocate for water custodianship, or locally governed datasets of citizen-sensing campaigns. The accessibility and portability of the *Kinect* accord with participatory environmental monitoring and citizen sensing frameworks that treat sensors as catalysts for situated inquiry, shared learning, and local decision-making (Palermo et al. 2017).

Hyyppä et al., (2017) show that Kinect can capture tree stem diameters with practical accuracy in the field, and propose crowdsourcing forest inventory by landowners using low-cost depth sensors, contributing local measurements to improve national biomass maps. The device inhabits the utility space of gaming peripherals and *Ecological Citizenship* technology simultaneously: not solely an object but a set of affordances for autonomous action. A living-room game sensor became a civic instrument, enabling non-experts to generate situated forest data, calibrate remote sensing, and participate in custodianship without total dependence on central authorities.

The continual evolution of *Kinect* beyond its target domain reinforces the point. What was designed for entertainment persists in art, robotics, and measurement domains as citizens redesigned its purpose in context. Microsoft ultimately folded the off-target uses of *Kinect* back into the product roadmap. After the hacking and creative repurposing wave, it released *Kinect* for Windows with an official SDK and a 'near mode' function for close-range interaction suited to kiosks, clinics, classrooms and labs, explicitly expanding support beyond conventional and intended use-cases. That pivot later matured into *Azure Kinect DK*, a developer kit aimed at computer-vision and enterprise scenarios and closely correlated with the depth sensing used in *HoloLens*, signaling a wholesale move from game peripheral to general-purpose sensing platform shaped by real-world uptake (Bonnington 2012; Microsoft n.d.). This mutualistic approach to iterative design models a potential structure for the reflexive development of technology as a process that anticipates plausible futures with those affected, incorporates situated ecological knowledge, and stays responsive as meanings and uses change in practice.

Multistability can be more effectively addressed not as a design flaw but a condition of practice: technology becomes a set of relational capacities that can either widen agency or, if intentionally restricted as a response to unintended use, retreat to narrow utility. Designing and implementing such devices as Ecological Citizenship technologies means attending to their affordances, their accessibility, and the social arrangements by which communities can use them in context (Bunting 2025). We summarize this overview as: ***Multistability >*** *(multiple, context-dependent meanings) Works across domains, across cultures and across platforms.*

Perverse Incentives and Paradoxical Consequences

This multistable possibility inherent in the design and production of technological objects and systems means that their deployment must be continuously assessed. Even technologies with well-structured goals can have contradictory outcomes. Technologies intended to serve ecological goals may inadvertently reproduce the very structures they seek to disrupt. Infrastructural design initiatives such as green stormwater installations can inadvertently distribute pathogens in groundwater, acting as an accidental conduit for environmental cross-contamination (Taguchi et al. 2020). These paradoxes concur with discourses of technology as pharmakon (Kern 2014), simultaneously remedy and poison, with an awareness of the potential asymmetries in this conception (O'Gorman 2022). This necessitates anticipatory ethics, multistability as a design consideration, and a transition from instrumental tools to technologies considered in their existential dimension. Alternative strategies must acknowledge this ambivalence without defaulting to reactionism or reductive solutionist impositions, through approaches that embed feedback and ethical foresight into the design process.

Much of the potential misalignment in the deterministic expectations of a technological intervention with the complex unfolding of its deployment exists in the unilateral often relationships ingrained in the process and design of technological production. This means that an imperative component of an Ecological Citizenship-centred approach to technology is the inclusion of an encompassing understanding regarding the motivation of diverse populations, systems, lifeforms and relationships as fundamental in the design process.

The *ECT Framework* examines how unintended consequences can be anticipated, mitigated, or re-channeled through principles of ecological co-design and systemic awareness. In engaging this complexity, authors promote *anticipatory ethics*: an approach that embeds ethical reasoning into the iterative design of sociotechnical systems without expecting perfect foresight, remaining aware of the potential for restrictive, prescriptive or paternalistic solutions that can inadvertently attend future thinking (Nordmann 2014). Structured approaches to this understanding exist as concepts and practices like *mutual shaping* (Winkle et al. 2019) and *ethical foresight analysis* (Floridi & Strait 2020). Codes of practice (Wisconsin Society for Ornithology, n.d.) which position responsibility in relation to ecological systems rather than solely serving human interests can embed ethical post-deployment reflexivity as a fundamental value. More progress towards the amelioration of these potentially problematic effects have been initiated as collective ecological intelligence in the context of Ecological Citizenship through *Participatory Scenario Planning* (Boyd et al. 2015; Galang et al. 2025; López-Rodríguez et al. 2023).

These foresight techniques enable design spaces where collective values, material futures, and ecological consequences are interrogated and rehearsed, instead of being prescribed and determined, allowing designers and communities to encounter complexity with situated speculation rather than expert judgement. Ecological Citizenship research demonstrates how in-situ co-design exercises, rooted in participatory governance and emergent from community knowledge, serve as ethical foresight tools, redistributing authority from technical specialists toward shared ecological agency (Gooding et al. 2025).

While the *ECT Framework* positions anticipatory ethics and systemic foresight as necessary correctives to unilateral technological imposition, it is essential to not to attribute them oracular powers. A genuinely Ecological Citizenship–centred approach must include motivations, interrelations, and lifeworlds across populations, systems, and more-than-human domains from its inception. The *ECT Framework* addresses this by anticipating, mitigating, or rerouting unintended consequences through ecological co-design and systemic awareness. But foresight tools are not neutral (Jørgensen et al. 2008). Umbrello et al., (2023) critiques conventional anticipatory ethics for overconfident assumptions about legibility and control, arguing that

futures are always partial, selective, and socially shaped. Meanwhile, Foster's *Future Mundane* (2013) stance warns against designing only for extremes or fantasy, prioritizing futures rooted in ordinary life, resisting compression into grand narratives and triumphalist heroic models.

To counterbalance the shortfalls of rigid foresight tools, the ECT approach should embed reflexive feedback loops, plural forms of projection, and ethical readiness calibration. For example, de Jong (2025) proposes *Ethics Readiness Levels* that map how and when different ethical framings (outcome-oriented vs meaning-oriented) are appropriate, given technological maturity and uncertainty. Likewise, *Infrastructural Speculation* suggests methods that emphasize long-term relations, decay, and emergent use (Wong et al. 2020).

We propose a shift from designing *for* futures to designing *within* emergent processes, enabling communities and designers to monitor, reassess, and reorient together in situ. By prioritizing epistemic humility, adaptive ethics, and the mundane into the ECT position, we preserve its normative force while resisting technocratic determinism and overspecialized prediction. We summarize this overview as: ***Ethical Foresight >*** *ethically looks to the future and considers balanced perspectives.*

Polycentric Arrangements

The presumption of mutual exclusivity between bottom-up communal action and top-down systems of control obscures the potential for effective implementation of environmental initiatives in their hybrid configuration. Evidence from environmental monitoring shows that approaches connecting community knowledge, local priorities, and institutional capacities as a compound system yield robust outcomes, coupling participatory sensing and locally reciprocal ecological practices with state or agency infrastructure. Hybrid networks increase data quality, legitimacy, and persistence over time, simultaneously prioritizing situated knowledge and experience (Eicken et al. 2021).

Bottom-up processes promote contextual legitimacy and care in place; top-down organization cultivates enabling conditions: open data standards, long-term funding, policy protection of commons, cross-scale coordination and longitudinal monitoring. Co-production methods like anticipatory ethics reveal hazards and compromises early in the process, whilst multistability-conscious prototyping prevents over-specification and promotes open-use, guided by end-of-life planning from inception. This form of hybrid approach promotes autonomous, communal practice in accord with ecological and institutional outcomes.

This hybrid logic is also evident in the *Citizens Air Complaint Programme* (New York City Department of Environmental Protection, n.d.), through which community reporting of idling vehicles is integrated into municipal enforcement infrastructures. Local observation and civic participation amplify regulatory reach, while institutional frameworks provide the authority and continuity necessary for enforcement. The result is a hybrid system in which situated knowledge and community action are directly coupled with administrative capacity, reinforcing the broader case for distributed, polycentric environmental governance.
Polycentric governance (Carlisle & Gruby 2017) offers an architecture for such hybrids. As an alternative to a solitary command node or an atomized field of local domains, polycentric orders distribute administration and governance across multiple centres which coordinate, learn, and adapt across scales and systems. This configuration can correlate ecological processes between institutional and local decision venues (Steen 2020), distribute error-correction mechanisms and promote local autonomy through constructive regulation. Moves from monocentric administration structures to polycentric arrangements have been seen to improve cross-scale and adaptive capacity when roles, resources, and accountability are explicitly defined (Chazdon et al. 2020; Ostrom 2010; Wiegant et al. 2022).

For design practice, this means treating Ecological Citizenship technologies not as isolated artefacts but as distributed implementations situated in a polycentric field: created in collaboration with others, non-extractive in operation, intent on catalyzing autonomy, yet interoperable with civic and regulatory systems that secure continuity, equitable implementation and mutual safety. Hybrid forms of organization can improve distributional and procedural outcomes when civic standards, scientific expertise and administrated finance are paired with local ecological custodianship and local knowledge. Systematic reviews indicate that hybrid governance modes support ecosystem services and detriments according to contextual necessity, reinforcing the case for situationally adaptive planning of governance structures which are mutualistic from the outset (Asl & Pearsall 2022; Toxopeus et al. 2020).

Conclusions and Futures

Rather than closing possibilities through prescriptive models, future research must remain adaptive, contingent, and critically productive. Authors call for speculative propositions that extend the principles outlined; non-extractive, designed with-not-for, catalytic of autonomy, contextually appropriate, and systemically entangled, toward uncharted epistemological and ethical terrain. Those prior principles are the bare minimum required to navigate this knotty and interconnected terrain. Authors propose a research orientation that remains critically aware of technology's risks, simultaneously resisting binary oppositions of nature and technology through speculative, regenerative, and participatory design. Authors must contend with what cannot be known in advance: the subjective, affective, and relational dimensions of technology that resist quantification. Ethical unknowns demand reflexivity. How do we design without presuming who or what counts as a beneficiary? How do we stay accountable to more-than human worlds? Research, then, becomes a form of adaptive choreography; an open-ended process of learning with ecologies, rather than prescribing them from outside.

When we neglect to see technology as entangled with ecological systems we risk overlooking cascade effects: small interventions that, when aggregated or extended across time, may precipitate regime shifts or destabilize system dynamics (Rocha et al. 2018). A design choice that seems benign locally or temporally might, when scaled or prolonged, fracture ecological homeostasis. In neglecting technological praxis as essential to Ecological Citizenship, we become vulnerable to invisible harms, relational ruptures, and the erasure of more-than-human constituencies. Within our expanded consideration of Appropriate Technologies, these failures are potentially fatal: a technology that is not constitutive of ecological reciprocity becomes an externality, a reductivity that escapes accountability. As such, the horizon of future research must work toward appropriateness *at* scale and appropriateness *across* scales. Technologies will increasingly operate within systems they cannot fully model. This necessitates flexibility, iteration, and embeddedness. Our framework encourages engagement with the unknown; not as a deficit to be eliminated but as a condition to be designed with. Future work must embrace contingency as a design principle. This framework (see Figure 1) has been built on the typologies and examples within our Network+ funding project and offers a steer to their conceptual repetition. Authors are aware that delivering the 'holy grail' of all elements is exceptionally challenging and if there can be a strategic direction toward *Ecological Citizen(s) Technologies*, it will be a better path to travel. These 'way points' speak broadly to audiences at a high level so they can be appropriated, as the main conclusion has been identifying modalities of repetition, learning and steps to a more ecologically enabled world.

Ecological Citizen(s) Technology Framework

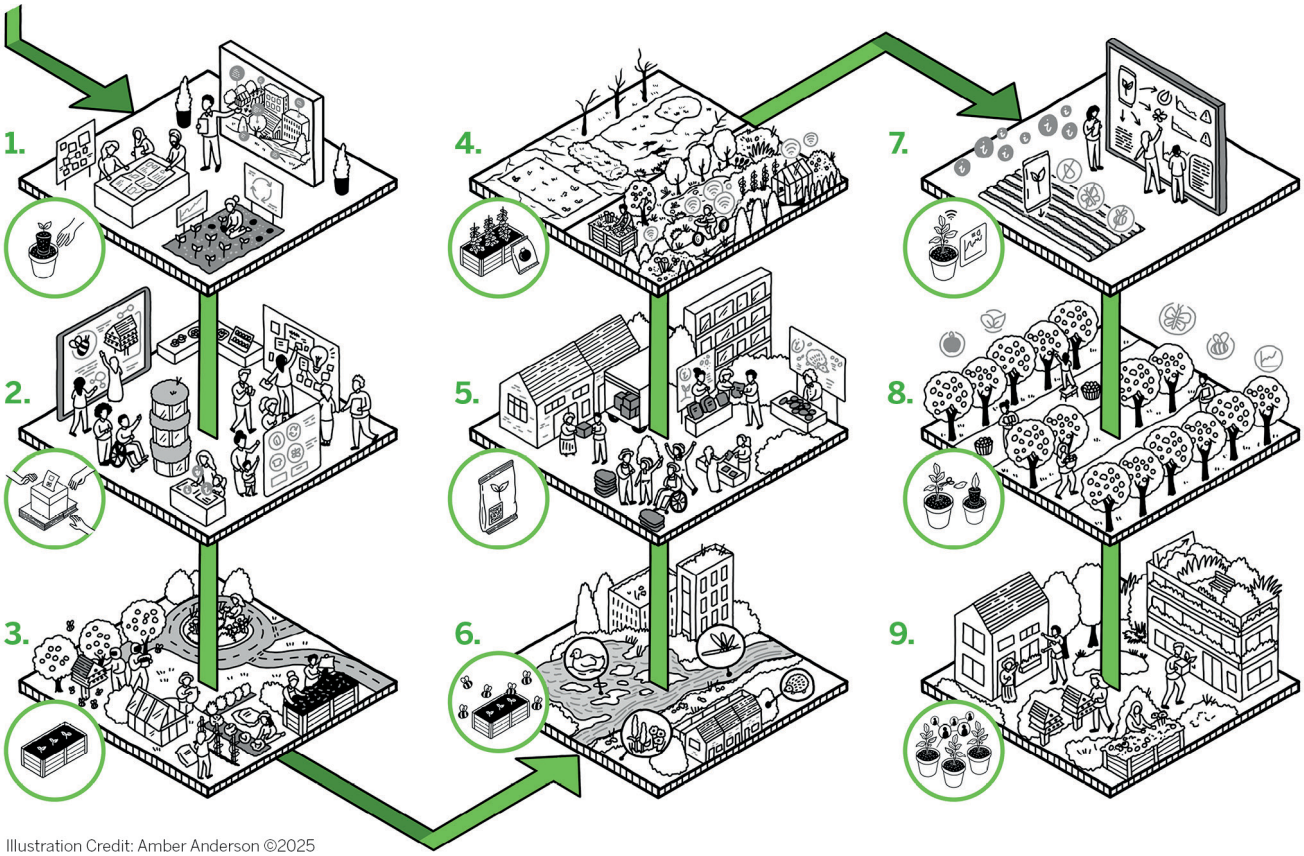

Illustration Credit: Amber Anderson ©2025

1. Sustainable Intentions *(core)*

The proposal initiation and intent is to build sustainable practices.

2. Designed 'with, not for' *(core)*

Designed with people, openly in collaboration, not inflicted upon them.

3. Benefits wider communities & each other *(core)*

Through its actions others benefit, like planting flowers, pollinators benefit, as do allotment owners.

4. Planet & Natural World Benefit(s) *(core)*

Deep consideration to the surrounding environment.

5. Accessible

Easy entry point(s), low friction interventions, could be inter-generational, considering its life over time.

6. Multistability

(multiple, context-dependent meanings) Works across domains.

7. Ethical Foresight

Ethically looks to the future and considers balanced perspectives.

8. Stewardship & Considers End of life

Proposition considers its end of life, its subsequent stewardship.

9. Intent on Autonomy

The proposition yields autonomy with Citizen(s) not reliant on governmental powers.

We are the Ecological Citizen(s) Network+. Our mission is to explore and catalyse Ecological Citizenship for positive climate action in a sustainable digital society.

Ecological Citizen(s) Network+, EPSRC award (EP/W020610/1). **ecologicalcitizens.co.uk**

Ecological Citizen[s]

Figure 1: The Ecological Citizenship Technologies Framework, compiled from literature and practice-based projects.

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Bamboo for People and Planet

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Abstract

Regenerative systems design creates entrepreneurship that aligns economic growth with ecological resilience and social justice. Industree Foundation works to empower rural women to build regenerative enterprises rooted in natural materials in the emerging regenerative economy. This paper examines bamboo-based livelihoods that restore land, capture carbon, and strengthen local economies. Its design-led model integrates the cultivation of indigenous species, decentralized zero-waste production, through farm clusters that own processing hubs. Collaborating with industry and government missions, Industree's initiative seeks to engage one million women across India. This scale requires collaborating with the government. Buy-in is key in aligning national objectives with value chain development by engaging with government resources in the field. Technology tools like UGAO, a mobile-based app, ensure traceability and transparency, while carbon certification and social auditing validate long-term impact. AI-assisted microlearning allows continuous and contextual knowledge upgradation. Products and technology in the downstream value chain complete the circular loop.

Keywords: Bamboo value chain, equity and social justice, regenerative-economy, systems design, value chain design.

Climate Equity and Gender Opportunity as a Trifecta for Good

The Industree Foundation works at the confluence of climate, equity and gender opportunity. Industree's work, historically, with natural fibres has established that nature-based, local materials sequester carbon and bring meaning to users and makers. Industree takes a design-first approach to enable vulnerable rural women to own and operate their entrepreneurial ventures, earning a dignified income.
It was established in 2000 by industrial designers Neelam Chhiber and Poonam Kasturi, with Gita Ram, a crafts activist, and later joined by industrial designer Jacob Mathew, who served as CEO from 2014 to 2023. Industree organizes women's collectives in the creative manufacturing sector, ensuring equity, inclusion and gender opportunity. The enterprises are owned by the people who work there and are equipped with the capability to deal with global value chains.

Industree currently works with the Natural Fibres Value chain, Non-Timber Forest Produce, Cottage-level food processing using hyperlocal distribution, as well as the Bamboo value chain. It plays a catalytic role in promoting enterprises and handholds them to achieve self-sustainability. Through its Regenearth Programme, it disseminates its learnings through a peer learning cohort-based capacity building programme that it conducts at six-month intervals. 25-30 social enterprise leaders at a time take part, and since 2020, over 250 enterprises have undergone the programme. Industree has also developed an online marketplace for creative manufacturing enterprises to market their wares online[1].

Image 1: A collection made for IKEA by Green Kraft Producer Company, incubated by Industree Foundation. Credit: IKEA

Industree Foundation's First Principles

1. Livelihoods are key to a community's development, enabling them to invest in their health, education, habitat, culture and security.
2. The means are as important as the end, and Industree's interventions will put people and planet, with the regeneration of natural and social systems at the core, working with nature rather than attempting to control nature.
3. Livelihood initiatives will be driven by a market orientation, ensuring there is demand that is fulfilled by the supply from livelihood activities for which a strong and growing market can be established.
4. Industree Foundation is design-driven and develops systems interventions and the necessary ecosystems of support.
5. The problems that Industree works on are much too big for one organization to tackle, and therefore, it necessarily co-creates solutions rather than merely collaborate and shares and learns with others aligned to the same objectives.

1 https://www.flourish.shop/

Design for Impact at Scale

In 2015, Industree Foundation launched its Mission Creative Million, an initiative that sought to expand its scope to bring sustainable, fair and equitable livelihoods for a million women. Smallholder farmers (less than 2 hectares of land) account for 92% of farmers in India, according to the 2015-2016 agricultural census, or between 475-510 million globally (Food and Agriculture Organization 2019). Landless agricultural labourers and craftspeople account for another 300-400 million people globally, including at least 200 million landless labourers, of whom 140 million are documented to be in India, and another 50-100 million craftspeople, estimated globally.

Of course, many artisans and craftsmen also double as smallholder farmers and landless agricultural labourers. Industree Foundation has chosen this as its target community. The programme was launched after the initial research looked at regeneration, agroforestry and the market.

The Industree team was also inspired by the work done by Professor M.P. Ranjan, one of the first designers in India to recognize the potential for bamboo for sustainable development. He was also an advocate for growing bamboo outside the forests in small and medium sized farms. His work in bamboo and cane from the mid-1980s right up to his untimely death in 2015 has resulted in shining a light on this material that is traditional yet affords a path into a sustainable future.

The Colonial Forest Acts of 1865, forest policy in 1869 and the Forest Act of 1927 increasingly restricted the use of forests by anyone except the government. The Act of 1927 classified bamboo as a non-timber forest product, imbuing only the forest department with the right to fell it, sell it (through auctions) and move it (permits from the Forest Department were required for bamboo to be transported). The Forest Rights Act of 2016, while allowing the transport of bamboo without permission of the forest department, still classified it as a non-timber Forest Produce. This, however, created confusion at the state level in how this was to be interpreted. It was only in 2017 that taxonomical classification clearly identified bamboo as a grass and not as a timber in the regulation, allowing its growing, felling and transportation if it did not originate in the forests. There were many brave attempts to set up bamboo-based industries in the 1990s and early 2000s most of which failed or did not scale.

Arguably, it was only in 2017 that bamboo could really be considered as a viable value chain backed by a potentially stable supply chain of material. China, on the other hand, had no such restrictions and continues to occupy the centre stage in bamboo cultivation and processing. Industree started its early pilots in 2019, which, through the pandemic years, continued in a very low key. 2022 was really when activities could be organized at any meaningful scale for impact.

The opportunities afforded to the agro-forestry sector, which included soil regeneration, carbon sequestration and livelihood opportunities at scale, were studied. Matching species to agroclimatic zones helped clarify which species, indigenous, endemic or exotic, were suited. Industree focused on indigenous and endemic species and not on exotic species, which also have the potential to become invasive under certain conditions. Exotic species are also more susceptible to blights, fungi and pests than indigenous and endemic species. The cultivation and use of bamboo was also selected as an area for development, building on the experience Industree had of natural fibres value chains. We found that designing with bamboo, the fastest carbon-sequestering plant, promotes biodiversity, but only if not cultivated in large swathes as a monoculture. Bamboo plantations can support livelihoods at scale, and are building the blocks for the Next Regenerative Economy. Bamboo not only regenerates degraded soil, but it can also be a substitute for many of the hardwoods coming from forests across the world.

However, it would be necessary to design high quality products to change the perception of bamboo as merely a poor man's inferior timber but as a strong durable alternative comparable and even better in strength and durability to expensive hardwoods. Given that most of the commercially viable bamboo species to be planted have a four to five-year time to maturity, supplementary sources of income through intercropping medicinal, spice and aromatic plants were studied. Further, once the canopy closed over and the ground was in shadow, shade-loving plants are also planned in the system.

Image 2: Bamboo 3 years after planting in Shimoga District, Karnataka (India).

Current Status of Impact

- Number of farmers in the plantation programme as of end of 2024: 7000
- Number of farmers added in the monsoon season of 2025: 16 480
- Number of farmer groups formed as mutually beneficial trusts: 12
- Number of farms certified under Forest Stewardship Council: 539 and 6390 farms under process
- Number of primary pre-processing centres in operation: 1
- Number of primary pre-processing centres under construction and equipment procurement: 3 before March 2026
- Number of bamboo hand craft centres established: 12
- Number of individuals working in the hand craft centres: 257
- Number of states with MOUs signed: 6 (Maharashtra Telangana, Andhra Pradesh, Odisha, Arunachal Pradesh and Tripura)

Potential for Impact Over the Next 5-8 Years

One million small holder farmers across India plant bamboo on a third of their holding usually on degraded land or land unsuitable for agricultural use, and gain supplementary income. Impacts include:

- Respecting biodiversity, rejuvenating the soil and sequestering carbon, to create a carbon absorbing industry not just a carbon neutral one.
- Creating an income stream with minimal labour inputs after the first two years of planting. Income increases steadily over the first 8-10 years of planting, after which the number of culms harvested steadies for the next 30-40 years.
- A lifetime of value generation for 40-50 years per planting cycle.
- Create a downstream value chain for many industrial-scale and cottage-scale enterprises.

The Importance of Design

Design brings a holistic approach to integrating diverse actors and subsystems vital for an ecosystemic and circular perspective, as opposed to a linear one. It is because of this holistic and systems approach that design works where traditional methods have failed to solve wicked problems. Roger Martin, then with the University of Toronto, had championed this in his book *The Design of Business* (2005).

Today, thanks to the work and awareness building of pioneers like Donella Meadows, Rachel Carson, Thomas Berry and others that we have come to realize that designing with nature, rather than controlling nature, is the more sustainable and even more economical way in the long term. Using indigenous and traditional ecological land stewardship knowledge systems guides us to a path of beneficial mutualism, which can shape a new ‘ecocene’ age in place of the ‘anthropocene’ epoch where humans and nature work in concert (Mihnea Tănăsescu Politics of the Ecocene 2022).

Design also prompts one to think holistically and examine what are often considered externalities and unforeseen consequences of success. Biodiversity is nature’s way of growing resilient ecosystems. Modern agroforestry depends on monoculture for ease and efficiency, and if bamboo is successful, that could be an unintended consequence, if big business decides to go in for industrial-scale farming, especially on forest department ‘wasteland’. Globally, bamboo for industry is dominated by Moso bamboo from China. Moso bamboo covered 527.76 million hectares in 2021 in China (National Forestry and Grassland Administration 2023). Monoculture at this scale is unnatural and worrisome. Some locations across China, Japan, India and even the Caribbean have documented bamboo species introduced in new areas becoming invasive.

Image 3: Entire hillsides planted with bamboo near Fuzhou (China).

A 2023-2025 study by the office of the Principal Scientific Advisor to the Prime Minister of India places 126 million farmers as smallholder farmers, each owning up to 1.5 acres of land, which is much smaller than the global definition of smallholder farmer at two hectares or five acres of land. Industree has chosen to work with farmers who typically own just one acre of land, for whom additional livelihood opportunities are critical. Industree raises 15 species of bamboo, endemic to India, that possess commercial value and are suited for specific agroclimatic zones. Farmers grow three to five species suited to their agroclimatic zone to mitigate risk. Only a third of an acre is planted with bamboo; on average, about 60 clumps of bamboo are planted in a third of an acre. The yield from the fifth year onward climbs from about seven to eight culms per clump to 10 – 15 culms by the tenth year. A third of an acre by the tenth year will be yielding up to 900 culms per farm per year. Food security is not affected. Most of the land used is degraded land, land on slopes too steep to till, or not currently used to grow food crops.

Ensuring that the growth of bamboo is on agricultural land and putting an economic value on seeds, so that they are collected and not disbursed into the wild, and collecting wildlings, (seedlings from the wild), especially in the north eastern states of India, is but one incentive to prevent the uncontrolled spread of bamboo and prevent endemic species from becoming invasive.

Distributed but aggregated networks of small-scale farms, organized into hub-and-spoke clusters, create economically viable fractal units. A group of 20-30 farmers forms a farm cluster, and 10-20 farm clusters are aggregated into a collective that operates a primary pre-processing centre, serving 400-600 farmers. The primary pre-processing centre ensures that the first step of value addition accrues to the community.

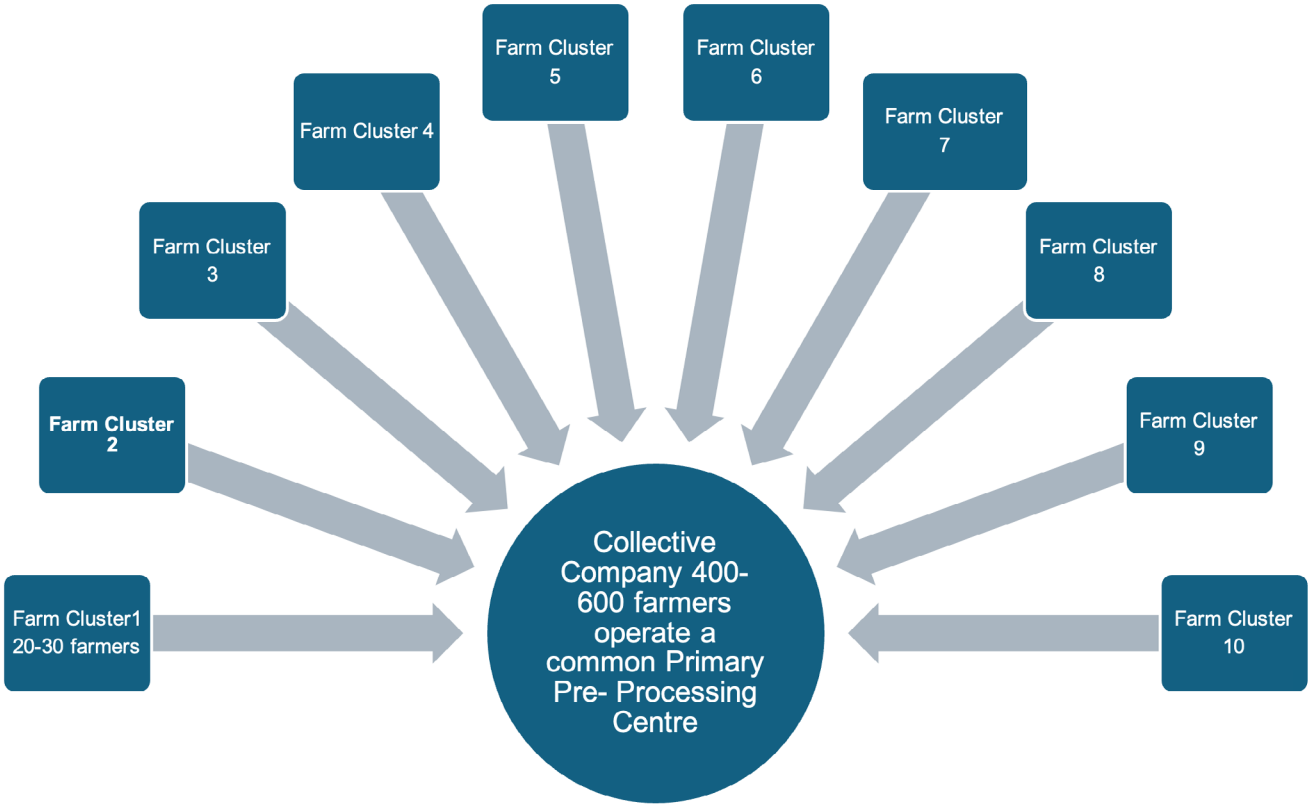

Figure 1: Organizing structure for farms with the first value addition preprocessing captured by the farmers' collective. Credit: Madhan K M, Industree Foundation

Locating the Primary pre-processing centre close to where the bamboo is grown, usually not more than 40 kilometres away, ensures that the harvested bamboo can go through a pre-product processing phase that can make meaningful, viable material that is ready for the next stage of specialized value addition process from a transportation cost perspective. Every value addition phase creates material in the form of shavings, chips and dust, which, if produced in quantity at a single site, can then be converted into economically valuable 'waste' by-products like fuel briquettes, charcoal and biochar.

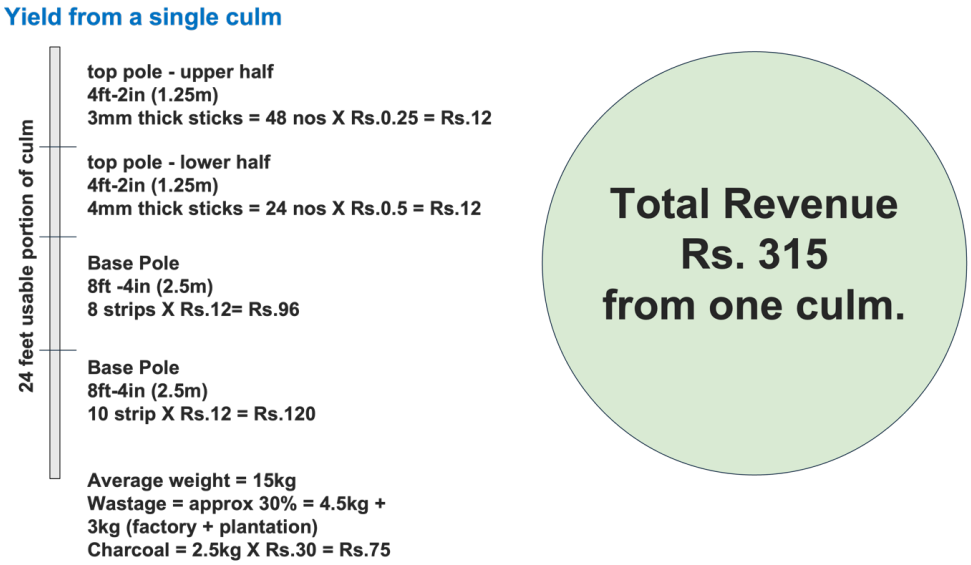

Figure 2: Designing a zero-waste business model is a crucial aspect of Industree's work, and every bit of bamboo has a use. The prices are from 2024. Credit: Madhan K M, Industree Foundation

A culm fetches not more than INR 100 at the farm, but treated poles can be sold for scaffolding for up to INR 160. The primary processing centre, by utilizing every bit of bamboo, can earn as much as INR 315 (approximately USD 3.5) from a single culm.

A primary pre-processing centre, with 600 farmer members, can pay out close to 58 000 INR in year five, going up to INR 124 000 by year 10 at today's prices to every farmer in the group. This assumes a 8% production bonus to members on the value addition at the pre-processing centre. In addition, benefits like soil rejuvenation, carbon sequestration to the tune of 17 tonnes per hectare per year or 2.2 tonnes every third of an acre can also benefit both community, individual and planet.

Image 4: The bamboo value chain from seed to market. Credit: Vinod Valsalan, Industree Foundation

The pre-processing centre is then the node from which supplies can be made to a variety of industrial and creative manufacturing enterprises. Even the shoots of the growing tip of the bamboo culms can be converted to edible bamboo shoot products and even fermented for a bamboo beer.

Bamboo is split and processed into various sizes and shapes in pre-processing plants as close to the plantation as possible. The external skin and the first few layers are used for artisanal mat and basket weaving; the inner woody part is cut into slats, some of which are converted into sticks. The slats and sticks are sent to secondary and tertiary industrial units for conversion into end-use products. Incense sticks, chopsticks, toothpicks, or woven products, such as blinds, are examples of end-use products. Boards and beams for the construction and interior design industry emerge from the slats. The secondary and tertiary units are owned and run by mainstream entrepreneurs that the collective companies supply to. All the waste, including internodes, powdery inner surfaces, dust, shavings, and chips generated, is converted into briquettes for charcoal production, as well as for ethanol and pulp production. Bamboo charcoal is used for water filters, air purifiers, cosmetics, and pharmaceuticals. Bamboo can be a zero-waste production process.

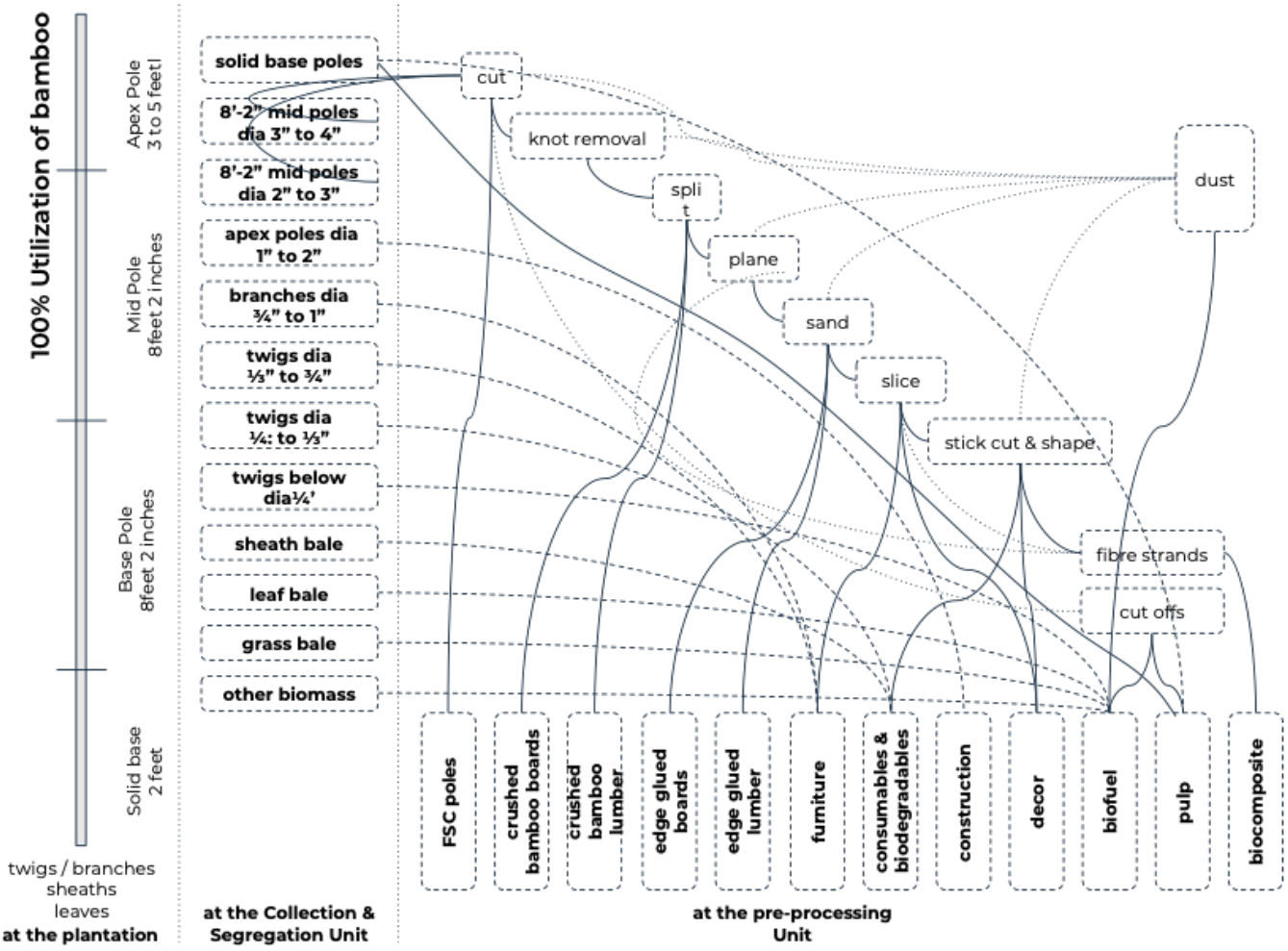

Figure 3: Utilization of bamboo is mapped to processes and industries that can use it. Credit: Madhan K M, Industree Foundation

Network of Co-creators

An effort of this scale and scope requires radical co-creation. Industree works with a network of partners like universities of agriculture and forestry, and national research institutes, The Bamboo Mission of India, The Environmental Bamboo Foundation, The Foundation for Revitalisation of Local Health Traditions and the Transdisciplinary University, Srishti Manipal Institute of Art Design and Technology and numerous individual experts and researchers. The government of India, at both the national and state levels, is unlocking INR 1 billion in funding to enable one million women to plant bamboo with Industree's technical assistance (Day-NRLM 2023).

Design for the Downstream

A key element of Industree's systems design approach is design for the downstream. The programme, from inception, has engaged with industries that process bamboo into end products. A series of meetups with potential industrial users has revealed demand for various kinds of feedstock for industrial processes. The support that has been enlisted from government programmes for the supply side is complemented by efforts to understand the demand side and draw in-principle commitments from industrial users.

Ethanol

Chipped bamboo put through a fermentation process developed by a Finnish company has been adopted by a state-owned refinery. A hub and spoke model of farmers supply bamboo to entrepreneurs who run chipping units, who then aggregate and pre-process material, densifying it, to transport to the refiner's biodigester and ethanol pilot production unit. It has been able to match the price of ethanol produced to a little less than price of petrol, making it a viable additive for the 20% ethanol mix now mandated in India. The byproducts generated included furfural, a green chemistry platform chemical with applications across a wide range of industries, acetic acid and food grade CO_2 with the residue powering a co-generation powerplant creating a net zero processing industry.

Rayon and Textiles

Rayon and viscose traditionally used bamboo as a feedstock; however, the processes employed in the 1980s and 1990s were highly polluting. It's only recently that closed-loop treatment systems have been developed, which recycle up to 95% of the chemicals and water employed. A process industry for pulp-to-bamboo fabrics in Harihar, Karnataka, has a daily requirement of 1000 tonnes of bamboo pulp as feedstock; unfortunately, this is currently met by imports from China, as the supply from India has been inconsistent. Discussions with the leadership have assured us that an uninterrupted, consistent quality and quantity of pulp is a no-brainer for them to plug into.

Briquettes and Fuel and Coal/Coking Coal Substitutes

Regulatory changes that mandate non-fossil fuel substitutes for the cement and steel-making industry have opened up an urgent requirement both as fuel and for reduction processes. Two of the largest steel and cement manufacturers have expressed interest to use agroforestry-derived coal substitutes. Their mandate is to reduce non-renewable inputs in steel making by 20-40% and in the cement industry by 20-30% in the next five to eight years. It is in our interest to under-commit and over-deliver. The delivery and transportation distance is an advantage here as coal traditionally has had to travel long distances, as too often the distance between mines and fuel sources is often increasing.

Charcoal

Bamboo charcoal is considered second only to coconut shell charcoal, and finds uses in making activated charcoal used for air and water filtration and used in pharmaceuticals and cosmetics. The need for air filtres in domestic use is growing as are personal care products where charcoal powder is used as a cleanser for skin.

Construction Furniture and the Interior Design Demand for Bamboo Boards

China has been the pioneer in manufacturing laminated bamboo boards for the furniture, home accessory and flooring markets. In recent years, bamboo has also been used as a green cladding material in prestigious projects like Bengaluru's Kempe Gowda International Airport Limited, which uses bamboo moulded in tubes extensively. The bamboo for the airport has been supplied by a Dutch company with manufacturing in China. Several plywood manufacturing companies in India have expressed interest in setting up lines for board making and laminated bamboo flooring. Architects and interior designers in several cities surveyed by Industree have expressed an impatience for using bamboo in their projects, especially for LEED certified buildings. Processes like glue lamination and cross-lamination have spiked interest in bamboo as a structural material and not just for cladding, as has been the case thus far. There is a global interest in laminated timber or mass timber construction of buildings up to 30 floors in height, already completed. A 55-floor building is under planning in Milwaukee (USA).

Mass timber was also used in building the perimeter ring for the recently concluded Osaka Expo 2025. Bamboo is still a way away from mass timber construction owing to limitations of wall thickness, but also because of availability in quantity, segregated by age and species and therefore material property. Most architects and designers predict a 30% saving in section size when compared to mass timber.

Bamboo Tongue and Groove Flooring

Bamboo flooring is still a popular flooring choice, as with the selection of the right glues, low or zero VOC (harmful volatile organic compounds) emissions have been achieved, and unlike other engineered timber floors does not require an under layer of fibre board, which has a higher percentage of glues and potential to off-gas.

Creative Manufacturing or Artisanal Production

The lowest investments are for creative manufacturing, which can be in the range of INR 10 000 to INR 100 000 per job created. In contrast, conventional manufacturing or robot-aided manufacturing can be as expensive as INR 10 000 000 per job created. Developed countries may find that human capital and employment at scale are not so much of an issue. In countries like India, our demographic dividend of an unprecedented number of youth entering the working age population could well turn into a demographic disaster if not enough meaningful, well-paying jobs are created in time.

10% of the bamboo grown in plantations is earmarked for use by the creative manufacturing industry, that we define as production wherein the value added is by creative intervention of hand, heart and head. The hand represents artisanal skills, the heart represents the social fabric and the head represents cognitive reasoning with embedded intergenerational cultural knowledge.

Community Owned Pre-processing Unit

The pre-processing unit, owned by a farmers' collectives, ensures that value added in the first step of downstream processing accrues to the farmers. The preprocessing centre is equipped with electrically operated machines like de-knotting, both internal and external, sizing, splitting, slivering and slat making equipment. The slivers are then sent to artisanal production units for weaving, mat making and decorative accessory making. In addition, it also has machines to convert part of the slat output to incense sticks, cylinders that can then feed into chopstick and skewer making units. Currently, one unit is operational with three more set to start by March 2026. The majority of the slats will go to the furniture and interior fit-out industry for board making. The dust and chips generated are converted to briquettes or charcoal. A carburising unit for treating the slats and sticks has been ordered, as it is an essential step before converting to a product, as it reduces the sugar and starch content in bamboo and resists fungus formation and mites. By altering the temperature and duration of the carburizing process, the colour of the bamboo can be modified to a deep honey by caramelizing the sugars present in the bamboo, eliminating the need for dyes to get a darker colour. Several of these interventions, like incense stick making, skewer making and furniture making are intended as reference implementations to attract private sector players to also invest in setting up conventional for-profit enterprises to whom the farmers' groups assure a steady and consistent raw material flow.

Image 5: A pilot pre-processing centre produces material for product prototyping, where 10% of the output is allocated to artisanal units.

Image 6: A rendering for a knockdown bent glue-laminated table, developed for artisanal production using bamboo slats. Credit: Design Simon Singh, Industree design team

Reference Implementation to Grow the Supplier Base

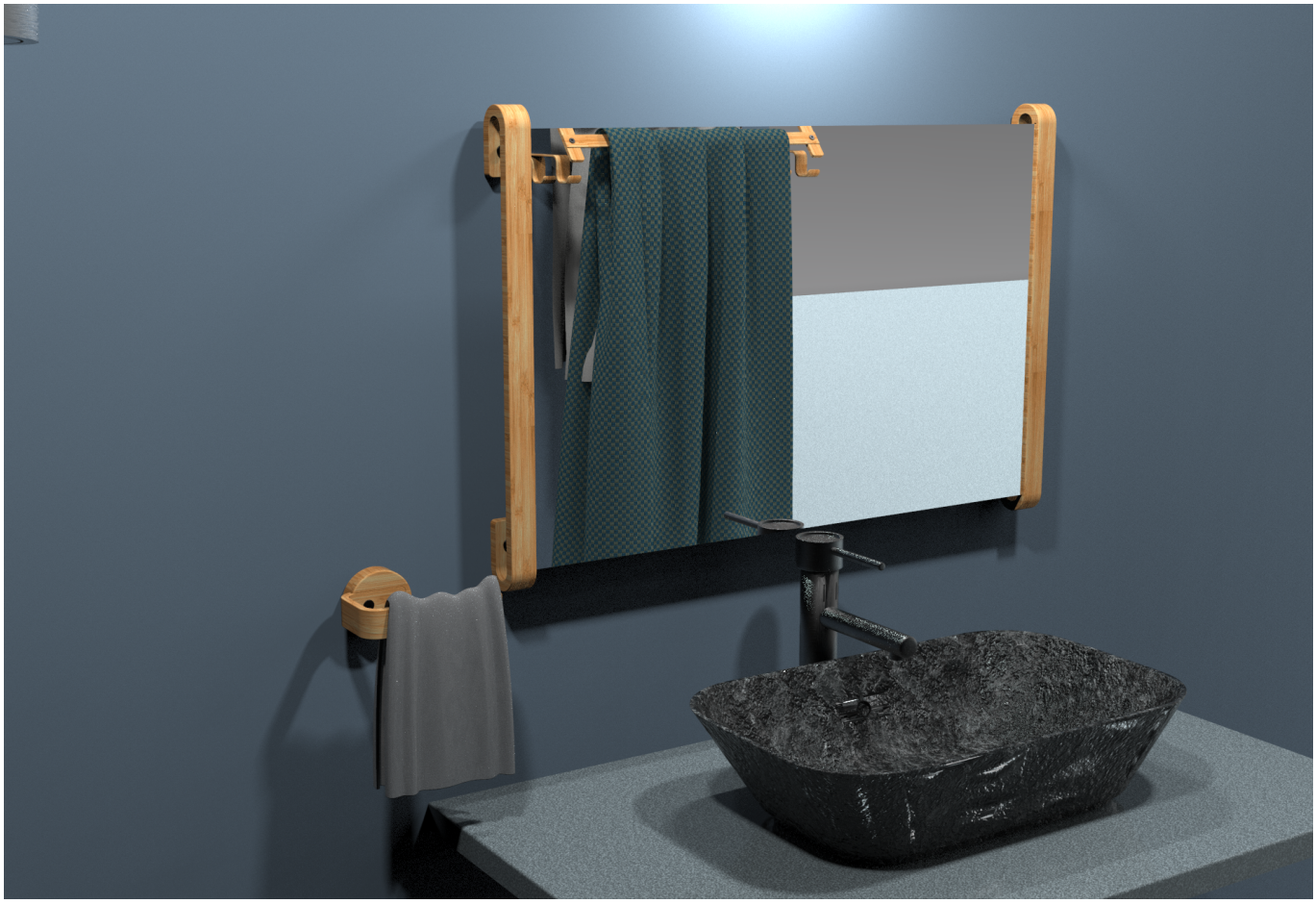

Image 7: Bathroom accessories made with laminated bent bamboo. Designed by Simon Singh, Industree design team.

Image 8: Glue Lam knockdown table with metal hardware. Designed by Simon Singh, Industree design team.

Image 9: Christmas decor from slivers made from fine bamboo slivers from the primary pre-processing unit. Designed by Dhirendra, Industree design team.

Designing for Scale

Working with the government is essential for scale, as the government, through policy, regulation and enforcement, can create the ecosystem that is required for a new industry to thrive. As demonstrated earlier, until the amendment of the Forest Rights Act in 2017, which clarified the policy, the industry could not get organized.

It requires a deep understanding of how government systems work and the drivers for sustained systems change to be able to work at scale. India's federal structure means that while the central government sets overarching policy, it is the states that have to implement the policy. This requires patience, persistence and relentless follow-up. Bureaucrats do get transferred, and very often continuity means repeated pitching to new incumbents to bring them up to speed. Generally, political changes do not overturn policy but merely slow it down during the transition period. The next most important thing, is to understand the schemes and policies unveiled by the government of the day and examine how one might integrate with the schemes announced by the government without losing the essential integrity of the programme. All too often, things can scale only if several of the drivers line up to align with a shared objective.

Government representatives were quick to see the alignment of this initiative with the Ministry of Rural Development's Lakhpati Didi Strategy (rural women earning INR 100 000 annually). As of 31 January 2025, approximately 10.05 crore (INR 100 million) households have been mobilized into 90.90 lakh (INR 9.09 million) self-help groups (PIB India 2025). These SHG members are the backbone of the Lakhpati Didi Strategy. The Government of India's National Rural Livelihood Mission adopted Industree's Bamboo Plantation model as one of its flagship sub-sector programmes. Over the next five to eight years, approximately one million women are expected to be directly involved in the programme, with many more working in downstream value chains.

The process of conducting workshops at the state level, sensitizing the state, district and block level officials to the programme, then identifying champions who are more receptive to the programme than others takes time and effort. The Community Resource Personnel (CRP) are then trained to take on the responsibility of mobilizing the farmers. The Industree team then does capacity building training for the CRPs.

The primary processing units will then be replicated like fractals based on the geography, accessibility and number of clustered farms. The state governments, through funds released by the Central Government, will underwrite the cost of the mobilization, training and building pre-processing centres. The cost of the Industree teams will met by Industree's own fundraising through corporate social responsibility programmes of Indian corporates, philanthropic donations and grants made by individuals and foundations and financial instruments like the REAL Fund (REgenerative Agroforestry Livelihoods Fund). This ensures that any government funding goes directly to the beneficiaries of the government schemes while Industree maintains its independence, agency and integrity.

Designing for scale also requires preparing for scale in terms of generating, analyzing and utilizing data for value addition, especially for traceability and transparency. Developing digital tools for communicating and maintaining best practices is also key. UGAO, or Grow, facilitates scale through a mobile app developed by the Industree Foundation that allows growers:

- To geofence their property
- Locate it using GPS
- Input data critical for growing bamboo
- Troubleshoot for instances of infestations or stunted growth
- Create a peer network of growers
- Contribute to traceability and transparency of the supply chain

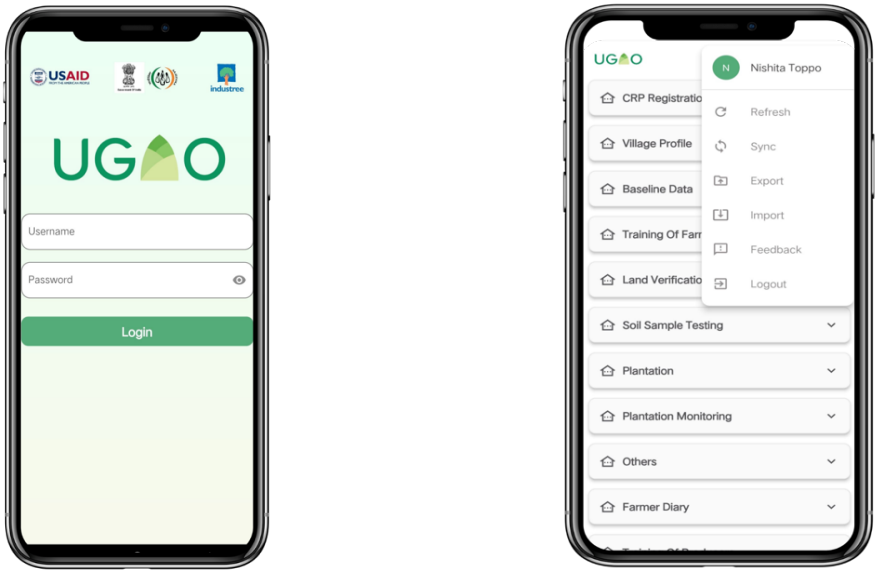

Image 10: Mobile app UGAO connects GPS location to cropping information and traceability.

Image 11: Nursery in Nashik, Maharashtra, that can grow close to two million seedlings a year from seeds.

Designing for scale has necessitated ensuring high-quality seed stock is grown into saplings, ready for planting. The three nurseries established by the industry can currently supply three million saplings a year; this year's requirement alone is 1.3 million saplings. Industree doesn't use tissue culture propagation, as the experience for communities that have used tissue culture-propagated planting stock has been mixed. Bamboo flowers on a biological clock that is simultaneous across a species, and is independent of when a seed was planted, but is dependent on when the seed was formed. This phenomenon of mass flowering after which the bamboo dies and requires replanting in all but one or two species is universal. Tissue culture, unless rigorously implemented, does not document the biological clock imprinted in the material it utilises yet.

Impact Evaluation, Certification, Authenticity

Industree conducts a social audit review with independent observers using the UK's Social Audit Network (SAN) methodology once every two years. This measures social impact very much like a financial audit reviews financial performance annually. Industree and Verra are jointly researching carbon sequestration rates for various species in different agroclimatic zones. The Forest Stewardship Council has granted the world's first FSC certification to smallholder farmers, specifically to the first 539 farmers who began growing bamboo five years ago. In spite of recent setbacks, the climate and sustainability agenda linked to the UN SDGs will go on, as humans must thrive on the planet. Certifications like FSC are vital to tap into end-user businesses in the future, maybe not so much by legislation but by customer pressure.

Design methods and understanding stakeholder needs and aspirations are crucial for initiating and sustaining any systems change initiative. Design lies in the details, and creating narratives of the model through exhibitions and workshops has been crucial in garnering government support. Designers are not the heroes projected in the model, but are instead are the glue and catalysts that orchestrate complex ecosystemic activities, where each player is recognized and celebrated, bringing ownership and buy-in.

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Becoming Regenerative

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Abstract

This paper presents preliminary findings from the ESRC/AHRC-funded Becoming Regenerative project, which explores how design can catalyze radical regenerative practices and imaginaries, and how art and design education shape the emerging landscape of regenerative innovation. The project traces the journeys of innovators 'becoming regenerative' from their educational experiences to their entrepreneurial struggles. The findings presented here, therefore, span pedagogy, entrepreneurial ecosystems, and policy recommendations. This paper highlights key principles of regenerative design and the value of art and design education, which embraces unconventional, open-ended, and exploratory processes engaging with living systems. Imagination is examined alongside value-led systemic design approaches to understand how creativity becomes a generative driver of transformation. The paper also traces how regenerative ideas evolve from education to market contexts, where designers come to act as entrepreneurs. The tensions which emerge here – between ecological integrity, economic realities, and idealistic design visions – characterize regenerative transitions.

Keywords: Art and design education, imagination, regenerative design, regenerative innovation, value-led design.

1. Introduction

Regenerative design is increasingly recognized as a necessary response to intersecting ecological, social, and economic crises. Where sustainability frameworks have often been premised on minimizing harm within existing paradigms, regeneration goes further, actively attempting to restore, renew, and reimagine the systems in which we live.

While regeneration is often framed in relation to agricultural systems, design theorists such as Pamela Mang and Bill Reed (2007; Mang and Reed 2012), John Lyle (1994) and Daniel Christian Wahl (2016) understand regenerative design as an evolving paradigm that emphasizes systemic interdependence, ethical attunement, and place-based intelligence. Regeneration, in this design-focused view, requires an expanded imagination, active care, sense of responsibility, skills and agency. It requires serious and careful unpicking of how our actions are entangled within broader more-than-human worlds. It involves an affectual shift; a new mode of being, feeling and acting within the world to bring about transformational change in living systems (Wahl 2016).

In line with the Design Council's proposal to develop 'Skills for Planet' (2025), which aims to upskill 1 million designers with the 'green skills' needed to have a "maximum positive impact on the planet and its people" (ibid: 5), this paper considers the specific roles, responsibilities, and challenges faced by designers seeking to revitalize ecosystems through material, product, financial and supply chain innovation.

Building on the Design Council's valuable emphasis on practical competencies (such as selecting non-depletive materials and advancing circular strategies within current regulatory and supply chain frameworks) we suggest that regenerative design and innovation can be further strengthened through a more radical, systemic orientation. Through case studies of innovations with regenerative intent, we suggest that designing *for* planet necessitates not only working within current systems, but actively confronting and re-shaping them. Rather than limiting design practice and upskilling attempts to feasible optimizations within present structure, regenerative approaches require systemic rethinking of how materials are sourced, how value is defined, and how design interventions can shift the very infrastructures they engage with.

This paper emerges from the UKRI-funded Becoming Regenerative (B-Regen). While much regenerative theory operates within idealized or speculative framings, B-Regen examines what happens when regenerative ideas are applied, tested, and adapted within institutional, economic, cultural, and regulatory systems that may not inherently support them. The project's interest is in how regenerative design practices emerge, evolve, and gain momentum within entrenched systems that often inhibit the very change they seek to produce. We ask, how are creative design capacities and strategies leveraged within existing and emergent systems to create regenerative change?

We approach this question through the lived journeys of creative entrepreneurs working toward regenerative futures. These practitioners, often emerging from arts and design institutions, have developed projects across biomaterials, agriculture, ecosystem restoration, fashion, architecture, and more ecological product developments. Their work offers a powerful lens through which to examine design's role not just in making things or services, but in shifting systems.

Designers attempting to instigate regenerative outcomes must navigate between conflicting value systems: ecological ethics and market demands, long-term care and short-term viability, imaginative vision and regulatory constraint. This paper examines design's role in reshaping entrenched social, economic, political, and ecological imagination and systems towards more regenerative ends through a plurality of approaches.

Specifically, the authors trace:

- how designers within the regenerative paradigm engage with social, economic, political, and ecological systems as part of their creative design work;
- what kinds of institutional and cultural conditions are needed to better support regenerative design in practice;
- how regenerative entrepreneurs navigate the tensions between values-led design and the constraints of entrenched systems;
- and, why it is key for regenerative design to move towards imagination and a plurality of approaches, avoiding the dominance of optimization logics.

In addressing these topics, this paper aims to advance the theoretical and practical foundations of regenerative design and contribute to the recognition of design as a critical discipline in the regenerative paradigm and green transition.

2. Research Background and Methodology

The project informing this research is transdisciplinary, cross-institutional, and collaborative in its orientation, bringing together researchers and practitioners across design, biology, anthropology, sociology, and organizational studies. Hosted at the Royal College of Art, University College London, and Loughborough University, B-Regen explores how regenerative innovations emerge, evolve, and gain momentum within entrenched systems, taking the tension between regenerative aspiration and degenerative context as its core focus. Our focus is on regenerative innovation, as opposed to more commonly studied regenerative agricultural practice, as we seek to understand the contours of regenerative practices within design's field and parameters.

We have identified some distinctive characteristics of creative design practice as key for the development of regenerative design innovations. These are in line with the Design Council's (2021) *Beyond Net Zero Strategy* report which emphasizes a systemic expansion to design activities in a drive that relates to regeneration. A designer's ability to identify connections, be a "connector and convenor" (Design Council 2021) and "combine previously unrelated structures so that you get more out of the emergent whole than you put in" (Koestler 1989) relates to the regenerative innovator's ability to navigate complex ecosystems and create new synergies between its components. This role as an enabler of connections expands the notion of 'who is a designer' beyond the conventional product-related conception of this profession to organizations, systems, and relationships. As defined by Ezio Manzini (2025), "design, when everybody designs" expands the capacities of the discipline into social innovation spheres; as argued here this is central for regenerative design innovation.

The examples presented here demonstrate the ability of the project leads to exercise their creativity under constraint, whether economic, political or systemic. As put forward by craft writer Peter Dormer (1997), rules can act as an encouragement to innovation rather than a limitation in a creative endeavour. It is a well-recognized trait of designers that they can thrive within a restrictive framework and find novel ways to circumvent challenges, as with the initiatives developed by this research's case studies. As defined by the Design Council report (2021), this ability to work beyond silos and think in full systems is key to regeneration.

The methodological backbone of this project includes qualitative interviews, design research, ecosystem mapping, and speculative design prompts. By blending empirical inquiry with design research and speculative imagination, we seek to not only understand existing barriers and opportunities, but to generate actionable recommendations for how regenerative practices might be better supported across educational, entrepreneurial, and policy landscapes.

Within our participant recruitment and case study development, we take a deliberately broad approach to regeneration. This is for two reasons. First, regeneration takes time, yet regenerative innovation in the context of global production is still a relatively new phenomenon. It is therefore difficult to assess the effect of the selected case studies. While most of our cases are still in the process of establishing their impact, they offer insights into emerging regenerative qualities. Here it is important to acknowledge that regenerative practices have long been embedded in Indigenous knowledge systems (Watson 2019).

The scope of this study is limited to the selection of case studies which demonstrate regenerative innovation in a global entrepreneurial context.

Second, regeneration as an ideal requires whole systems change: innovators fixing a small piece of a broken system cannot be truly regenerative. Many of the cases presented below are therefore partial, emergent forms of regenerative action. We consider these efforts as valuable attempts at 'becoming regenerative'.

Two work streams are represented in this paper: our preliminary work on design courses teaching regenerative design (design pedagogy) and through our longitudinal cases which trace entrepreneurs on their journeys towards becoming regenerative (entrepreneurial journeys).

3. Design's Role within Social, Economic, Political and Ecological Systems

The transition toward regeneration is neither straightforward nor immediate. Designers operate within entrenched infrastructures that necessitate pragmatic translation of regenerative aspirations into actionable, context-sensitive strategies. This transitional terrain is marked by tensions between idealism and realism, innovation and compromise, individuality and collaboration.

To better understand how design functions as a vehicle for regeneration within these constraints, we begin by examining the systemic terrain that regenerative practitioners must navigate, and how design serves as both a product and a process of systemic engagement. Designs do not operate in isolation; outputs are always shaped by, and in turn shape, complex networks of material, economic, social, and ecological relations. Every design decision is entangled with conditions of labour, sourcing, regulation, manufacturing, logistics, funding, use, and disposal.

To explore this tension between regenerative aspiration and systemic constraint, considering how designers creatively adapt their strategies to bridge the two, the following section presents a series of case studies drawn from the B-Regen project and a few other key examples which exemplify regenerative practices. Grouped by the dominant systems they seek to address, the case studies presented in this section illustrate different strategies for advancing regenerative ends: from cultivating new social relationships and reviving ecosystems to shifting policies and redirecting flows of capital. These examples demonstrate how regenerative design emerges through situated experimentation, negotiation, and alignment with (or against) systemic degenerative forces across diverse geographies and sectors, including biomaterials, agriculture, fashion, architecture, and death care among others.

Through real-world projects, we highlight the potential of design as an approach, as a transformative process adaptive to social systems, socio-cultural ecologies, politics, and economic flows and as an outcome. Rooted in care, collaboration, and systemic considerations, these cases are presented not as polished solutions, but as provisional, experimental grounded attempts to engage design as a systemic practice that can reorient how value, care, and possibilities are distributed across people and planet.

3.1. Shaping and Integrating into Social Systems

Designers with regenerative intent must analyze how practices are continually shaped by social relationships, behaviours, and values — and how these, in turn, can open or close possibilities for change.

Consider the foundational work undertaken by HairCycle, a publicly funded research project in Newham, London, which explored the cultural and systemic constraints around reusing human hair. To propose a viable recycling system, the team first had to understand how hair might become a valued material within urban contexts and then identify both technical and social barriers within existing practices and infrastructures.

Through community consultations and workshops, the designers mapped the religious and cultural meanings attached to hair, the stigma surrounding its handling, and the infrastructures currently in place for its disposal. This informed a framework grounded in local preferences and built on relationships of trust, particularly between individuals and their hairdressers.

To embed regenerative practices in daily life, the project prioritized visibility and community engagement. Rather than operating from an industrial site, it set up a public-facing workspace on a local high street. Hair was collected in branded bins and transported via branded bicycles, making material processes (like collecting, sorting, manufacturing) that are so often hidden a part of the urban landscape. Workshops with schoolchildren and local residents encouraged a broader reassessment not only of hair, but of materials more generally. As Sanne Visser, founder of HairCycle, reflected:

"We're working with hair, but in many ways it's not just about hair, is it? It's about making people aware of where our materials come from."

Image 1: Sanne Visser on the hair collector HairCycle bike. Credit: HairCycle

Image 2: Hair-based felt-making workshop at the local community garden. Credit: HairCycle

A further example of socially rooted regenerative design is Studio Fernando Laposse's ongoing collaboration with the indigenous community of Tonahuixtla in Mexico. Over a decade, the project has worked to restore native corn species, regenerate degraded and desertified land, and support return migration through sustainable agriculture and flexible work while producing high-end collectable furniture.

The project adapts to the farming calendar and local capabilities. Furniture production takes place between harvests, in a workshop embedded in the village centre. Because the land is communally held, the project had to demonstrate shared, long-term value to gain support. Trust was built gradually, with success measured in ecological and social benefits such as increased water retention, wildlife return, and funds circulating back into the community.

For Laposse, several social aspects of regeneration are paramount:

"You have to have some sort of social regeneration going hand in hand with ecological regeneration...economic sustainability alongside ecological sustainability. I think the best way to really give proof that a system like this works is when you have a multi-generational engagement".

As exemplified in these cases, regenerative design is slow design, requiring deep engagement with local people and processes to build new resilient systems.

3.2. Engaging with Socio-cultural Ecologies

Within regenerative design, designers' attention extends to eco-social specificities: to the broader systems, structures, and expectations that shape how people relate to specific ecosystems. Laposse's work is one example of this, but so too are more technically oriented projects like *Materra*, an agri-tech company. While originally focused on producing traceable regenerative cotton through enclosed hydroponic systems, Materra shifted its approach through on-the-ground collaboration with farming communities in India. The project began to integrate indigenous agricultural knowledge and local practices, moving away from technological fixes toward a more ecologically and culturally embedded model. Materra's work spans the material supply chain: its *CO:FARM* app supports farmers in managing pests without synthetic pesticides, while also providing cotton buyers with traceable data on water use, carbon reduction, and improved soil health.

In the UK context, engaging at the start of material supply chains often requires close partnership with NGOs and scientists promoting new land-use practices. Ponda, a startup developing bio-alternatives to down and synthetic insulation from Typha (a wetland plant), collaborates directly with peatland ecologists, DEFRA policymakers, and farming communities to embed its innovation within broader restoration efforts. By encouraging the rewetting of fields for Typha cultivation, the project aligns material production with the ecological regeneration of degraded wetlands, treating restoration as both a design input and outcome. Through multi-stakeholder collaboration, Ponda connects fashion brands, farmers, and scientists to the paludiculture (wetland farming) movement. This not only helps de-risk a new agricultural model but also facilitates traceability, shared metrics, and transparency across the supply chain, ensuring that regenerative claims are grounded in measurable ecological impact.

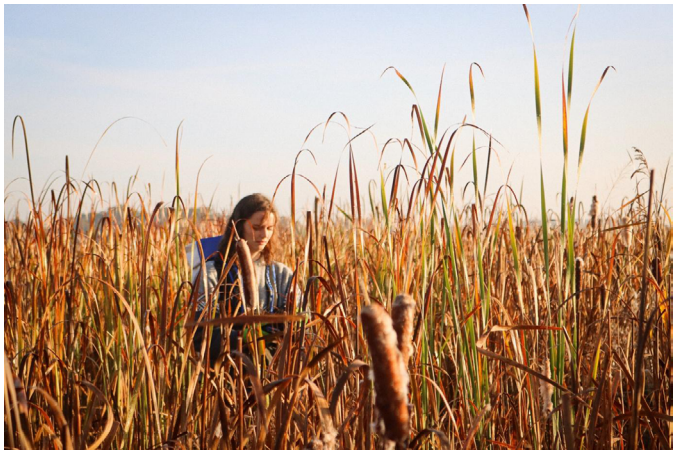

Image 3: Ponda cultivating Typha latifolia on re-wetted peatlands as part of the paludiculture project. Credit: Ponda

While Ponda grounds regenerative design in land-use and agricultural eco-social systems, other practices engage more symbolically charged terrains. Resting Reef, for instance, operates at the intersection of ecological restoration and deathcare. The project reimagines deathcare by transforming ashes and oyster waste into reef structures. While founded in London, the company has already established memorial reefs in Bali (currently in the pilot stage). It uses ritual and storytelling to connect personal grief with ecological care, prompting cultural shifts around death and environmental responsibility. Yet, the project also demands serious engagement with communities in which the reefs are being installed, ensuring people are comfortable with the installations and that the presence of the dead does not lead to socio-cultural or political discomfort.

3.3. Navigating Politics

Innovations in regenerative design are not neutral; they unfold within political landscapes that shape how materials, knowledge, and agency circulate. Navigating these politics requires attentiveness to rights, power, and the possibilities for collective action. We understand regenerative design's role as shaping new political forms as much as new material systems.

Take PhyCo, a Canadian company developing compostable alternatives to agricultural plastics from algae in partnerships with coastal communities. PhyCo considers its partnerships with First Nations and coastal communities as central to its approach. PhyCo ensures the seaweed it sources is harvested with respect to Indigenous sovereignty and environmental stewardship. Rather than sourcing raw materials in extractive ways (often from around the world), PhyCo foregrounds equitable collaboration. This model challenges dominant industrial norms and embeds regenerative design within a more just political ecology. Moreover, PhyCo aligns where processing happens, working with communities interested in deeper engagement in biorefining while also purchasing sustainably from those who prefer a more transactional role. This flexibility reflects an awareness of diverse political and cultural contexts.

Attention to the local industrial politics can reveal valuable leverage points for enabling a just transition (Morena, Krause, and Stevis 2020). One such strategy involves aligning regenerative materials within existing manufacturing infrastructures to reduce friction and build inclusive pathways toward regenerative futures. For example, Carbon Cell intentionally is designing its biodegradable biochar pellet for compatibility with existing plastics processing systems. By creating

pellets that work within established production lines, Carbon Cell invites existing manufacturers to participate in the green transition without requiring disruptive overhauls to their equipment, processes, or personnel. This approach brings added social value to sourcing and production by acknowledging the realities of labour within industrial ecosystems.

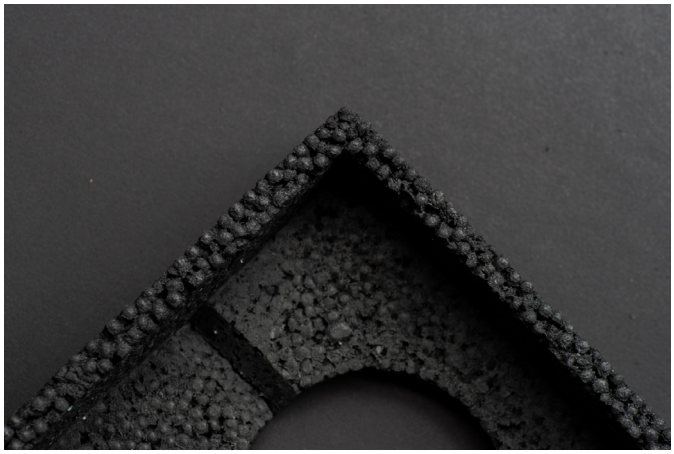

Image 4: Carbon Cell biochar material made in a press to match conventional machinery. Credit: Carbon Cell

Having a means to act on environmental issues matters. On the Isle of Wight, Artecology, a nonprofit focused on enhancing marine biodiversity in intertidal zones, employs a highly participatory method called *CoCreate* which involves local communities in the creation of artificial rock pools (Vertipools) on seawalls. The Vertipools serve as a kind of living public installations, inviting residents to engage physically and emotionally with ecosystem regeneration. Instead of using expensive 3D printers and complex modelling, the Artecology team encourages forms of material complexity through hand-crafted clay structures with high rugosity and bioreceptive value. As Nigel George, the creative lead, put it, by embracing peoples' innate capacities and diverse creativity, they could "start simple and let the complexity take care of itself." Artecology's Vertipools are more effective than conventional eco-engineering projects.

As an organization, Artecology is highly adaptable as they link culture, ecology, and politics, it can draw upon arts grants as well as more straightforward funding streams to support its ecological projects. Nigel argued:

"What we're scaling is a movement and not a product... Every time we develop something, we're thinking about how we can indigenize this approach so that anyone, anywhere in the world can do what we do."

He framed it not in terms of design universalization, but as a way of locally restoring agency to people; to invite them, in a tangible way, to engage with the challenging work of mitigation and restoration.

Other projects engage directly with policymakers and broad publics. Biobased Creations, a Dutch creative studio, concentrates on weaving disparate bio-based innovations into shared public narratives and spaces. By collaborating directly with policymakers and local governments, Biobased Creations aims to shift public perception and institutional acceptance of alternative materials and practices. Their work illustrates how regenerative design can transcend isolated projects, influencing broader systems through storytelling, public engagement and demonstration.

Image 5: Artecology's Vertipool with bioreceptive hand-made forms. Credit: ArtEcology

Similarly, Danish architectural practice EFEKT exemplifies nuanced political engagement by mobilizing architects, municipalities, and national authorities to reduce the carbon budget for the built environment. Their collective lobbying effort has led to the Danish government agreeing to 40% tighter CO_2 targets than initially agreed, incentivizing material transitions and lower-carbon solutions. The approach acknowledged the existing tensions and concerns within the industry, showing how regenerative aims can be pursued through collective problem-framings and coordinated policy advocacy. As one of the architectural leads put it, the approach worked because:

"We didn't ask single suppliers or manufacturers to change the way they built. We asked everybody to agree that everybody has to change the way they built. So nobody had to be out there and spend extra money...We're all in the same boat, and if we're on the same boat, it's the same rules."

In terms of the disconnect between economic and political literacy and the skillsets of architecture he noted "if you don't understand finances, you don't speak the language of politicians or policy". Pointing towards the issue of externalities he referred to the tension of the real system – the physical system – and the constructed system "there is a real system at stake, we're just not accounting for it". Currently EFEKT is taking this further in their "Butterfly Framework" by extending the carbon reduction curve while simultaneously fostering the regeneration of the natural world.

These cases demonstrate that navigating the political dimension of regenerative design requires more than technical innovation. It involves building equitable partnerships, creating spaces for community agency, and engaging with governance structures to shift systemic conditions. The relationship of regenerative practice to the powers and structures in place described in the quote above reveals a tension between two approaches. On the one hand, creative change makers appreciate the need to infiltrate and operate within existing systems and bring change from within, onboarding stakeholders across a system by offering implementable regenerative transitions. On the other hand, much of regenerative design's discourse articulates a need to dismantle and replace existing systems. Innovators in this space often find themselves grappling with these challenging contradictions or attempting to navigate both approaches simultaneously.

3.4. Mobilizing Economic Flows

If politics shapes the distribution of power and possibility, economic systems often determine what regenerative efforts can scale or even survive. Yet, of all the systemic constraints regenerative designers face, economic systems may be the most entrenched and least forgiving. Existing models of investment, production, and valuation are often fundamentally misaligned with regenerative aims. Nevertheless, by creatively working within and around these systems, innovators are creatively exploring what kinds of futures it can fund.

OysterHeaven, a European firm dedicated to restoring oyster reefs, offers a compelling example of financial design attuned to ecological regeneration. Rather than valuing oysters as a consumable product, the organization presents them as ecosystem engineers whose value in filtering water, removing nitrogen, stabilizing coastlines, and fostering marine biodiversity can be neatly priced. This pricing is not about the intrinsic value of a restored reef, but the value of its ecosystemic benefits *for* specific audiences. By speaking the language of asset markets, OysterHeaven reframes reef restoration as a measurable, investable asset class. “I wanted to work out if there was a financially viable way to fix the gaping holes in marine ecosystems around the world,” explained the founder, George. The aim is not simply to secure funding, but to realign capital flows with the long-term ecological health of the ocean.

Other forms of financial creativity might be found in more relational and place-based economies. Returning to Studio Fernando Laposse, their work draws value from a different kind of asymmetry. By producing intricately crafted, labour-intensive design pieces for the highest-end collectible market, the project redirects wealth from affluent markets in the Global North to support ecological restoration and community resilience in the Global South. This model is made possible by the convergence of two conditions: the time-intensive nature of the work, and the limited employment opportunities available in the region. Yet, Laposse’s approach doesn’t seek to industrialize production or increase output, but instead honours the natural rhythms of agricultural life and local capacity. It carefully balances the economic value assigned to craftsmanship in the art and design world with the lived realities of those producing it. Rather than exploiting inequalities, the project navigates them deliberately, turning global demand into a mechanism for sustaining local futures.

These cases demonstrate that regenerative design practices require designers to move across social, ecological, political, and economic terrains. What unites practitioners across projects is the capacity to think systemically, to anchor decisions with ethical reflexivity, and to collaborate in a caring manner with other human and nonhuman actors.

Image 6: Community-based agave replanting. Credit: Fernando Laposse and Pepe Molina

Image 7: Marquetry workshop using corn husks in Tonohuixle. Credit: Fernando Laposse

4. The Value of Design Education in Shaping Regenerative Futures

This capacity to translate systemic insight into tangible form positions design as a powerful tool for regenerative transformation. Yet this potential is continually shaped and constrained by the very systems it seeks to change. Design, in this context, becomes a medium for navigating and negotiating entrenched infrastructures. We theorize regenerative design as systems-dismantling design; in its early emergence, as presented in many of our entrepreneurial cases, it might be traced through systems-redirecting strategies. This is part of the process of 'becoming regenerative' in which designers identify and leverage points within complex existent systems where their interventions might lead to larger changes (Meadows 1999). This also resonates with Mazzucato's (2018) 'Mission-oriented Innovation', which emphasizes moving beyond incremental fixes to pursue bolder and broader systemic transformative alternatives. These interventions are not always fully 'regenerative' in outcome, but they serve as footholds where regenerative thinking begins to influence dominant processes.

We believe that the capacities necessary for system-redirecting are not incidental; they must be learned, cultivated, and refined. This raises a question of *how* design education might better prepare students to navigate the kinds of systemic complexity and constraints required to bring about regenerative futures. In the following section, we briefly examine the role of design education in shaping mindsets, skills, and ethical orientations for regenerative practice.

In recent years, art and design institutions have become vital incubators for regenerative intent. Historically organized by material or medium (e.g., product or graphic), many design institutions now, especially at postgraduate level, are reshaping their pedagogy in response to global instability, ecological urgency, and calls for systemic rethinking.

These are the spaces where the next generation of creative practitioners begin to grapple with the complexity of ecological crisis as ethical, material, and systemic challenges that design is complicit in (Fry 1999) and must respond to. At their best, design schools foster the conditions for students to engage in what we might call regenerative becoming: cultivating ethical awareness, systems thinking, and the courage to imagine and design otherwise.

Design institutions support this process by providing environments that are deliberately open-ended and exploratory. For instance, at MFA/MSc Innovation Design Engineering (IDE), the joint Master's programme between the Royal College of Art (RCA) and Imperial College London (ICL), students are prompted to imagine the impossible precisely because the real-world systems they are preparing to challenge are so deeply entrenched. One notable example of this is a paradoxical design brief to create a 'bed of nails'. This challenge was given to students to explicitly foster lateral thinking and help them become comfortable with failure. It invites designers to engage not with neat solutions, but with provocative conceptual and material tensions.

One of the values of art and design cultures is in being able to embrace the unconventional and the seemingly 'nonsensical,' where playfulness is recognized as a vital mode of inquiry (Fantini & Toivonen 2025). As Fantini van Ditmar & Toivonen (2025) argue, the catalytic nature of art and design schools can be explained by the relative absence of conceptual and practical constraints – students are encouraged to imagine new caring relational possibilities. These cultures often favour exploratory, open-ended processes that engage with living systems and prioritize regenerative potential over rigid methods or fixed outcomes. This openness enables unexpected pathways. This can be exemplified by MFA/MSc Innovation Design Engineering (IDE) projects – which have since developed into startups working on down and packaging replacements, respectively – sparked by a road trip or the case of the frying process of a prawn cracker inspiring the development of a biochar panel giving significance advantages when compared with science and technology approaches to manufacturing. Inspiration is often lateral; the founders behind Earthshot prize winner Notpla, for instance, were initially inspired by clouds during their Master's work at IDE and the ways in which it could deliver water without plastics. The founder also described a tutor's response to initial prototypes "focus on the clouds, not in the bubbles to deliver water" illustrating the value of openness and abstraction in design pedagogy, prompting the designer to reframe the problem at a systemic rather than a product level. Such examples highlight how regenerative imagination and nonlinear creativity can transform playful beginnings into meaningful and viable responses to real-world challenges.

The openness and creative freedom students are taught to embrace is not neutral. For many of the educators we've spoken with, a key question guides student assessments: in and amongst polycrises, does the world need this design? This deceptively simple question, asked repeatedly of student projects, serves as a provocation to think beyond aesthetics or novelty. It demands meaning, impact and accountability. It is the criteria by which educators reject gadgets or techno-fixes as sufficient responses, instead insisting on meaningful ecological, social, and political interventions that address real conditions and consequences.

Tutors emphasized that this was the criteria for success: does the project align to the student's proposed ethical framing and purpose? Rather than shielding students from complexity, this kind of assignment situates them within it and encourages them to develop critical and creative capacities needed to pursue regenerative ideas in contexts full of contradiction and constraint. Students are encouraged to cultivate their own criteria for what constitutes meaningful work, grounded in a regenerative worldview that treats humans and the environment as fundamentally interrelated, and that understands systems not as abstract models, but as living entanglements.

5. Constraints to Change: Roles and Remits Involved in Bringing Regenerative Innovations Forward

As regenerative design projects move toward real-world implementation, their founders often confront tensions embedded in the very systems they aim to transform. A significant number of cases remain situated within global trade structures whose underlying unsustainability is not yet fully addressed. Many of these challenges stem from role shifts: from value-led, systems-oriented design education to entrepreneurial practice embedded within market-driven and regulatory landscapes.

This transition is not merely practical; it is ontological. Designers trained to explore systemic ethics and material experimentation must now navigate the logics of markets, funding, and regulation. As projects move from educational institutions to market contexts, innovators oscillate between these different ways of working. Each role carries its own priorities and reward mechanisms. For instance, design as a modality prizes originality, functionality and aesthetics. It encourages risk-taking and individual authorship. In contrast, the technical or scientific mode is rooted in precision, replicability, and feasibility. Meanwhile, an entrepreneurial modality is driven by market fit, scalability, and navigating economic constraints.

These concerns are compounded by the ways in which design education tends to valorize individual authorship and novelty over collaboration and shared ecological impact endeavours. One founder of a successful bio-design start-up offered a frank assessment:

"Designers need to be more realistic while they are studying...Go figure out what you're really good at, go do that, and also acknowledge that you're part of a bigger system. Designers get the sense that they're going to solve things by themselves, when really they are not."

Yet, students are often prepared only for the first mode — designer — and therefore struggle with the pragmatics of long-term systemic R&D or with pitching a business and fitting into existing market logics. This is the slow work of systemic transformation (Irwin 2015): understanding the conflicting agendas of diverse stakeholders, and pragmatically working against them, slowly and incrementally. This includes navigating policy, understanding value chains, and committing to the slow, often unglamorous work of systemic transformations (Irwin 2015).

Indeed, challenges compound for entrepreneurs working on regenerative initiatives. While design education may foster regenerative capacity through systems awareness, imaginative exploration, and ethical grounding, sustaining regenerative practices in real-world contexts requires navigating, and at times reconciling, conflicting value systems. Here, they need new skills to fully 'design for the planet'.

As a first example, consider the challenge of aesthetic, haptic, and performance re-education required for regenerative innovations to be widely accepted. New bio-based and compostable materials are ephemeral — the *point* of their design is that they are designed to degrade — and yet industry material standards and regulations often penalize them for those qualities. Our participants frequently complained of legacy standards and expectations being applied to their work, of being asked, "will it perform like plastic?" and responding, "no, and that's the point!".

Accordingly, in the entrepreneurial journey towards becoming regenerative, designers must learn to navigate competing logics and value systems. For example, one of our participants emphasized the need to take a more active approach in shifting expectations:

"In the past, that may have not been our place — it's about like the customer's right - but I think we've taken more of an active approach, asking: 'Is this jacket going to be used like climbing a mountain? Or is this a walk-your-dog jacket? Because if it's a walk-your-dog, can we reassess the product positioning? Do you have a customer that could be interested in this, given the incredibly important impact metrics that it can hit?'"

Encouraging this kind of reassessment of both product standards and user expectation is becoming an essential skill for regenerative designers. But it also requires time, confidence, and fluency across multiple languages — design, marketing, regulation, and impact.

Further challenges emerge for regenerative entrepreneurs, many of whom also struggle to navigate regulatory environments built for older paradigms. For instance, Carbon Cell, a start-up producing biodegradable foams out of biochar, is penalized for not being recyclable, even though biodegradability is the more ecologically responsible path. Similarly, the founders of Mykor, a company working with mycelium-based panels for construction purposes, have had to lobby to have mycelium recognized not as a wood substitute, but as a material class in its own right, requiring new standards, metrics, and testing regimes.

In addition to regulatory misalignment, access to funding is a persistent barrier. Many regenerative initiatives do not conform to the logics of fast growth, rapid returns, or easily patentable intellectual property; as such, they can be difficult to fit into conventional investment frameworks. As one funding intermediary we interviewed explained:

"I've got over a thousand companies in my database: 90% of them are in the early stage, working on interesting solutions, but a lot of them are just ... A lot of these founders, small time constrained teams, are just chasing money. They're spending too much time chasing money, which is really hard to get, as opposed to innovating and deploying what they're working on."

Even when funding is secured, scaling production remains difficult, especially for organic systems that are evolving and context dependent. Another CEO participant described this dilemma as "the activation energy needed to get over that initial development hump is the issue". For more place-based regenerative projects, additional challenges include the difficulty of demonstrating long-term value — since regenerative returns often accrue over decades — and the complexity of embedding business practices in local ecologies and communities.

Nevertheless, many of the designers we've engaged with find creative ways to navigate these systemic frictions. While their models may not scale in conventional terms, they offer glimmers of what more just, ecologically-attuned production systems might look like. Here it is important to note that expectations of scale, risk reproducing unecological assumptions that prioritize expansion over contextual adaptation and ecological health. Each case reveals how material choices, organizational structures, and design strategies are shaped by (and shape in return) the broader systems they inhabit.

These design journeys speak directly to initiatives like the Design Council's 'Skills for Planet' reskilling push, which calls for equipping designers with the skills needed to navigate and influence systems for planetary good. The 'Skills for Planet' framework (2025) rightly identifies critical competencies for designing in the face of ecological crisis with its emphasis on systems thinking, co-creation, and problem-solving across circularity, emissions, and green communities. However, our research suggests that regenerative designers also require a broader and more radical creative repertoire that goes beyond responding to existing problems within the confines of current systems. Shifting material cultures, value logics, and institutional norms calls for capacities that are harder to codify, including the imaginative, political, and relational skills needed to inhabit existing systems while also envisioning and enacting alternatives to them. This leads us to the next theme: the necessity of design that can challenge, reframe, and reimagine systems, not merely *improve* them.

6. Towards Systemic Imagination and Plurality rather than Siloed Efficiency and Optimization

In the face of eco-social breakdown and systemic uncertainty, design must move beyond the constraints of the current systems. This includes the narrow models of efficiency and optimization that dominate conventional production as these siloed approaches (often inherited from engineering, industrial and managerial logics) limits the capacity to respond to complex, interdependent challenges. Optimization tends to isolate variables, narrow creative scopes, and reproduce the same systems that regenerative design seeks to transform.

Throughout our research, we found valuable insight from practitioners whose approaches resist linearity and instead embrace uncertainty, contextuality, and collaboration as core design values. This final section foregrounds design skills that go beyond redirecting existent systems, but towards generatively imagining radically reframing what is possible, what is valued, and how futures might unfold.

A good example of this kind of lateral thinking comes from Jan Boelen, the creative director of Atelier Luma. Boelen sees dominant "efficiency thinking" as not only insufficient to address systemic issues, but as an integral part of the problem.

"This mechanical mindset is what led us into many of the problems we face today. Each time a small fix is applied to address one issue, it produces another, which then requires yet another fix. We end up in a cycle of patching and repairing that only deepens the mess."

Flexibility and imagination often is more important than efficiency; as one of our case study start-up founders working on alternative fibres from agricultural waste described, "I used to think the goal was to optimize — make each step cheaper and cheaper. We would map out all the costs and say, 'If we optimize this step by 80% or even 90%, will it be enough?' And often the answer was still no. Some processes are simply never going to be cheap enough. So instead of pouring endless energy into optimization, we stopped. We began asking: what if we remove this step entirely? What if we stop assuming that a certain machine or process is essential - and instead design a different pathway altogether?"

By thinking outside of the existent system - and thinking away from efficiency logics - other paths forward might be found. For Fibe, the startup in question, this means keeping as many choices available as possible. As the founder put it:

"It's about maintaining optionality. Faced with two choices — one technology that is the 'best in the world' but only works with a narrow feedstock, and another that is less perfect but adaptable to many feedstocks - we always choose the latter. Flexibility matters more than optimization."

Boelen (Atelier Luma) presented a more radical counter-approach to optimization and efficiency: a vision of "abundance" which finds value where others see none, such as in local waste materials, fading industries, and overlooked ecologies. Drawing on a bioregional approach, described by Berg and Dasmann (1977) as a geographic area characterized by natural features such as climate, landforms, watersheds, soils, and native species, along with human cultures, Boelen suggests that this perspective offers a means of shifting narratives revealing that "things can be otherwise."

Such an approach, as he understands it, is fundamentally open-ended, inclusive, and responsive to local contexts. This lack of predetermination is key, as it allows diverse people to have stakes in the project:

"Design, in this sense, is also about bringing people together. For example, in the algae tableware project we gathered a farmer, a scientist, a startup, city residents, and a designer all around one table. That object becomes the meeting ground. Its aesthetic qualities - the touch, the feel, even the smell - are vital. I want to use the word beautiful here, because beauty draws people in. It invites them to become part of the project and part of the process."

From here, he suggests that a new material culture might emerge in which a community has shared stakes in a new material system. This is, in a sense, ontological and epistemic design (Willis 2006): design which shifts ways of being and knowing our world. It involves fundamentally rethinking sources of value, relations of production, and networks of use.

Design which is fundamentally regenerative must grapple with these primordial challenges. It is design rooted in locality and is relationally constituted. It requires a different orientation towards the creative process. For example, British Pasture Leather, a company creating an alternate leather supply chain to provide provenance to a commodity material, described their approach as 'doing things backwards'. The brand is founded by a fashion designer and a creative producer who has previously worked on regenerative farming. It uses hides from cattle raised on regenerative farms, mainly those certified by the non-profit Pasture for Life. As the founders described:

"At British Pasture we've done everything 'backwards'; at least from the perspective of the conventional capitalist commodity system. Instead of starting with the system's expectations, we start with what's at hand: this resource here, that resource there, this person, that person. And then we ask: what happens when we put them together?

By working this way, we've created something both viable and beautiful — a material that is incredibly long-lasting, full of potential, and, yes, more expensive. But the point is that by stepping away from optimization and linear efficiency, we find value in approaches that may seem backwards, but actually move us forward."

By freeing themselves from conventional assumptions around material processing and production, the British Pasture Leather team exemplifies a regenerative mode of design — one that centres imagination, relationality, and plurality over efficiency.

In moving beyond optimization and linear efficiency, these practices point to an expanded skillset for designing *with* and *for* the planet. As open processes and "backwards" methods can generate richer, more resilient design outcomes, designers must learn new forms of radical creativity, situated learning, and inclusive processes to build the capacity to break and reconfigure systems, not just improve within them.

7. Implications and Conclusion

Regeneration is a continuous, situated, and imaginative journey seeded in education, challenged by systems, and courageously re-ignited through creative, values-led design.

At its core, regenerative design is a form of caring systems design; more critically, it is a form of systems dismantling design. It asks not only how we might work within the current paradigm, but how we might begin to transcend and transform it.

This paper contributes to the emerging field of regenerative studies by foregrounding lived, practical engagements of creatives within regenerative design. The work draws both from longitudinal case studies on the lived experiences of entrepreneurs and on direct engagement and interviews with educators in the field, rather than relying solely on academic literature. As Daniel Wahl (2025) has recently noted, the academic bias toward peer-reviewed sources often obscures the role of practitioners and distorts the origin story of regenerative paradigms. In response, this work privileges real-world cases to help map the contours of regenerative design innovation as it is unfolding today. Practitioners rarely have time to write about their processes (Wahl 2025); this work attempts to fill that gap.

The authors foreground how regenerative designers are engaging with social, economic, political, and ecological systems as integral elements of their creative practices, which they navigate and transform through nonlinear values-led experimentation and interventions. In doing so, we aim to contribute to the conversation around the evolving competencies required for designers who wish to create regenerative change. These include the pragmatic skills needed to navigate and operationalize ideas within existing systems (as outlined by the Design Council's (2025) 'Skills for Planet'), but also more expansive and speculative capacities required to reimagine entirely new systems.

For regenerative creative entrepreneurs, support is needed through education and through policy, regulation, and funding mechanisms that might bring their innovations to scale. This demands wholesale systems change, which designers are uniquely positioned to contribute to. In the final stages of our project, we intend to re-engage the entrepreneurs we've interviewed to co-creatively think through alternate economies and policy structures.

For design education, this calls for educators to continue to nurture the nonlinear thinking and expansive creativity that they already excel in, but also to equip students with the practical tools, ecological knowledge and a plurality of examples necessary for implementing regenerative ideas in complex and situated real-world environments. They need to prepare students and graduates to think beyond their roles as designers — rethink systems, be ecologically considered, to ground themselves on place-specificities, to understand bioregions, to be resourceful, to trace interconnections and leverage points, and to consider how they will work in teams, under different roles and remits as innovator, entrepreneur, and technical developer.

Ultimately, for regenerative design futures to emerge, there needs to be a cultural shift that extends beyond design and beyond the academy. Without a move away from the paradigms of optimization, efficiency and techno fixes, towards deeper and more systemic understandings of interdependencies, regional care, and long-term flourishing of all life, regenerative designs risk being co-opted by the very optimization logic it seeks to displace. Design can and should play a central role in this transition, but to do so it must embrace its capacity to reimagine systems as much as reforming them.

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Climate Action at the Intersection of Feminism and Craft Practice: Developing a Theoretical Framework for a Regenerative Textile Design Pedagogy

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Abstract

Textile Design and other fields that fall under the umbrella of 'craft practice' are relatively new to academic study, due to the association of craft with women, marginalized, and Indigenous communities. Because of this, Textile Design is an ideal ground to explore experimental and critical pedagogy and emerging ideas of climate action and justice to respond to student needs. The innate connection to material core to textile practice and the role of the textile and fashion industries in the current environmental crisis create an undeniable requirement for sustainable literacy, and for a higher education pedagogy that engages with the reality of climate change. Building on established and emerging design frameworks such as Transition Design, Regenerative Design, Intersectionality and Eco-Feminism, we begin to co-develop a framework for curriculum with student-stakeholders which links the practices, livelihoods, and lived experience of women to the issues facing the climate and prepares them with the necessary tools and mindsets for their futures.

Keywords: Climate action, intersectionality, pedagogy, regenerative design, textile design.

1. Introduction

For many years, lively debate has persisted regarding the relevance or suitability of Textiles as a field of academic study; however, the contemporary definition of Textiles is now something even more complex and nuanced than the traditional craft disciplines it has grown from (Gale and Kaur 2002; Adamson 2010). The scope of creative processes found in Textile practice defy the historical divisions and definitions applied to it; these contradictions instead contribute to its manifold nature and simultaneously diverge into both craft and towards technology (Gale and Kaur 2002). Traditionally, textiles[1] provide warmth and protection, help us identify with each other, signal social status, and form a vital part of ritual and cultural practice. Textiles are inextricably linked with humans and have played key roles in human and cultural development since the first piece of string was plied in the Stone Age (Barber 1995). The textile industry has played a fundamental role in shaping the global political and economic landscape more than any other sector – with ties and roots in the colonialist movement, the Transatlantic slave trade, and the Industrial Revolution to name a few (Barber 1995; Gale and Kaur 2002). In contemporary culture, novel textile designs, fabrication and development, and creation of seasonal textile trends play key roles in the development of a booming industry and have heavily influenced consumer behaviour and mindsets (Gale and Kaur 2002). It's hard to find a part of human history or human experience not coloured by contact with textiles or the textile industry.

"Textiles are in the very grain of what we are – as we respond, so they respond, as we change, so they change. Because Textiles are so implicated in what we are, as an industry it has had the power to influence human destiny through social and political structures." (Gale and Kaur 2002)

Despite the magnitude of their global impact and role in shaping human history, craft practices and tacit craft knowledge passed down intergenerationally are often not granted the same respect in academic circles as the research and practice of either fine art or design (Adamson 2010; Igoe 2021). Whether this is because craft is often the practice of indigenous peoples, communities of colour, or women is grounds for additional debate; the result remains that craft- and those fields that have historically fallen under the umbrella of craft practice such as Textiles are still relatively new to comprehensive and legitimate academic study (Adamson 2010). Because of this relatively untread path, Textile practitioners and academics are not fighting entrenched preconceptions, long-established ways of working within higher education, or established routes from research methodologies to pedagogy. Critical evaluations of the Textile design process and the industry itself are few and infrequently published, and most current papers and research merely illustrate the areas in which Textile design activity is taking place across a range of industries, instead of articulating or defining what the process entails for Textile designers (Igoe 2021). Thus 'Textile design' in many ways still needs defining, and through working at this definition we can begin to shape more fully the methods for Textile design thinking and practice and scope out a pedagogy for the study of Textiles within higher education.

The connection to material that has always been core to Textile practice creates an undeniable requirement for sustainable material understanding and the need for this to reflect into the teaching of Textile practice in Higher Education (Barber 1995; Igoe 2021). Additionally, due to the role the Textile industry has had in contributing to the current environmental crisis, sustainable knowledge, capabilities, and literacy will be key requirements for the next generation of Textile designers as they enter an industry required to shift patterns of consumption and production to survive (Gale and Kaur 2002). Due to lengthy supply chains and energy-intensive manufacturing methods, the textile industry generates 8–10% of global carbon emissions, superseding emissions from the aviation and shipping industries combined; up to 20% of global industrial wastewater pollution is caused by textile dyeing and finishing; and the textile industry generates roughly 1.2 billion tonnes of CO_2 equivalent, or nearly 10% of world GHG emissions each year (European Parliament 2021; Morlet 2017; UNFCCC 2018).

Global fibre production almost doubled between 2010–2020 (from 58 million to 109 million tons) and shows no sign of slowing as global demand for fashion continues to grow (Textile Exchange 2021; Ellen MacArthur Foundation 2017).

Higher education must also confront climate anxiety, which should be considered in shaping a future pedagogy that supports and responds to the needs of student-stakeholders. The phrase climate or eco-anxiety has risen to prominence in the last decade to loosely describe worries owed to a changing climate, and research is showing that these feelings are becoming increasingly common (Tsui 2024). The Climate Psychological Alliance more broadly defines "eco-anxiety" as heightened emotional, mental, or somatic distress in response to dangerous changes in the climate system (Clayton 2017). These feelings of stress and distress are especially prevalent in young people, who often express dismay at inheriting an unstable future, and have lived under the looming spectre of climate disaster their entire lives (Bednarek 2024). A recent global study, which surveyed 10 000 young people from 10 countries, showed that nearly 60% of them were extremely worried about the future state of the planet (Hickman et al. 2021). Nearly half said that this distress affected them daily and three-fourths agreed with the statement "the future is frightening" (Hickman et al. 2021; Hossain 2022). Similar research investigating the impact of climate change on 10 000 university students in 32 countries found that it was impacting young people across the globe, with a quarter of respondents saying they felt "terrified" about climate change (Ogunbode 2022). A February 2022 IPCC assessment was the first to mention how temperature increase, trauma from extreme events, and the loss of livelihood due to climate can negatively influence mental health, noting that young people, older adults, and those with pre-existing health conditions are the most vulnerable (IPCC 2022). And at a 2022 United Nations conference in Stockholm, the World Health Organization released a new policy brief that discussed how climate change poses serious risks to people's mental health (World Health Organization 2022).

Image 1: Youth protest at COP28 during the final day of negotiations. Credit: Jennifer Dranttel

Thus, any relevant education for young people must hold space for and acknowledge the constant toll on mental health from their environment, and how living under the shadow of this crisis shapes their worldview (Tsui 2024; Bednarek 2024). While it might be scary and seem counter-intuitive to many educators, a future-fit pedagogy must introduce and embrace themes of Climate Action and Justice to empower students in the roles they can and must take up in their

[1] It should be noted that in this text, "Textiles" is not used interchangeably with cloth; the term in this article will be used to describe the entire gamut of textile applications.

futures (Tsui 2024; Bednarek 2024; Servant-Miklos 2024). These conversations create safe and supported spaces for processing grief alongside educators and encourages students to feel a sense of agency to take forward action (Bednarek; Servant-Miklos 2024). Enabling space for this conversation within education is a vital tenant of a proposed framework, and a direct response to the global context the framework sits within. Pedagogy must be contextually defined, and it must respond specifically to the conditions, formations, and problems that arise in the sites where education takes place (hooks 1994). Rather than treating pedagogy as a commodity, progressive educators need to engage with their teaching as a theoretical resource that is both shaped by- and responsive- to the very problems that arise between the spaces, places, and contexts that connect classrooms with the experience of everyday life (hooks 1994; Freire 1970).

In this vein, situating a Textile design curriculum within higher education in 2025 (and beyond) must address the social and environmental impacts of the textile industry, the required changes to industry and mindsets, and the impact of all social, political, and environmental factors on the students navigating the educational system. The nature of Textile thinking and Textile practice is to be both of its time and situated in a specific place, and so must a Textile design pedagogy be (Gale and Kaur 2002).

2. Existing Design and Pedagogical Frameworks

The following frameworks have been selected as relevant to Textile thinking and textile practice, and their values and methods can be viewed as Feminist. The implied (and at times explicit) link between craft practice, textile tacit knowledge, and the sphere of women's work makes a Feminist praxis a relevant sorting and selection metric. These selected frameworks are considered and discussed, and a resulting amalgamation is defined and proposed as a future methodology of Regenerative textile design practice and pedagogy[2]. The following is not intended to be an exhaustive list of influential frameworks and theories, as environmental theories often build on, borrow from, and intertwine with other related areas.

2.1. Eco-Feminism/ Feminism and Ecology

The term 'the Feminist Movement' can be used broadly to define a series of global struggles to uplift the plight of women, seek political, economic, personal, and social equality of the sexes, and put an end to sexism and gender discrimination (Mellor 1997). This movement can be divided into four waves, each of which seeks to tackle gender disparities and experiences in increasing detail. The first wave addressed the fight for women's suffrage (late 19th century), whereas the current 4th wave movement (2010s- present) is defined by more nuanced and contemporary discussions of issues facing women, such as body positivity, challenging rape culture, advocating for trans rights, and applying intersectionality (Munro 2013).

The second wave of Feminism, after women's right to vote was widely achieved by the early 20th century, co-emerged with both the burgeoning American civil rights and environmental/Earth Day movements in the 1960s-1980s (Munro 2013). This wave of feminist action, research, and scholarship sought to explore societal gender norms, women's roles in society, and deeply entrenched biases around womanhood. Feminists at this time began to push back about women's roles, even while many reclaimed postures and attitudes of femininity. One defining characteristic of this wave of Feminism is an overlap with the Environmental movement, which led many activists to define and quantify our relationship to the Earth through a lens of motherhood. Many slogans for the first Earth Day (22 April 1970) referred to "Mother Earth", which was also a sentiment shared in the emerging Gaia Theory, which identified the interconnected and nurturing nature of planetary systems (Lovelock 1972). Women's bodies and menstrual cycles, as well as typically 'feminine' acts of care, were seen to correspond to natural cycles of birth, growth, decay, and regeneration and the overarching ebb and flow of the planet itself (hooks 1994; Thomas 2022).

Codifying this link and building on the foundation of Feminist second wave thought, Ecofeminism is a philosophy and movement that identifies the dual oppressions of both women and the environment as rooted in patriarchal structures (Mellor 1997). It is a movement that sees a connection between the exploitation and degradation of the natural world and the subordination and oppression of women (Mellor 1997). Both women and the planet are assigned value through their ability to please and serve men – particularly white men – and to reinforce the pervasive economic system of capitalism (Tsui 2024; Thomas 2022). Ecofeminism also seeks to highlight voices that have been historically ignored, and vulnerable populations that have been violated and oppressed. Ecofeminists propose that if we're not aware of the patterns that rule our society, we are inclined to repeat the same injustices and will not tackle the climate crisis at its root. We cannot ignore the role of patriarchy, racism, and other injustices if we hope to have effective climate action and justice (Tsui 2024, 108).

Historically, women have become associated with textile production and craft because through childbirth and childcare, women needed to take up categories of work appropriate to the domestic environment. (Gale and Kaur 2022). Such arguments are often developed further to suggest that women through their nature are adept at building community, and textiles manufacture generally requires a fixed location and a variety of activities (Gale and Kaur 2022). After Feminism, many women see the idea of gender-specific proclivities as a purely social construct, so the repeated dismissal of the innate creative stature of women becomes rooted in patriarchal biases. Decorative arts and crafts are granted less respect than other creative practices- by default a reassertion of women's rank in the arts (Gale and Kaur 2022). Canons of Art History have perpetuated myths of 'the great white male artist', which further establishes a hierarchy that favours oil paintings over crafts and textiles. This exposes the systemic sexism within Art History and how women's contributions were often ignored or negated (Parker and Pollock 1981). Even within Feminist circles, decorative textiles are either valorized or dismissed, as they are often felt to lean too closely into male articulations of female talents (Parker and Pollock 1981; Parker 1984).

Textile design is a gendered academic subject within the UK with a significant majority-female cohort at higher education. This gender divide not only leads to imbalance within the workforce but perpetuates the stereotype of textile production as unpaid domestic labour (Coulter 2023; Bell 2013).

The explanation of why in many developed modern societies more women than men undertake textile education is not straightforward. Certainly, there is no universal acceptance of preference based on gender so we must presume it's a social construction, a familiar and accepted belief about the talents and roles of women. We might equally presume that men have been encouraged to have negative perceptions about the practice of textiles. There are undoubtedly a range of sociological and Feminist answers to the subject and gender divide, but there remain some more difficult questions around issues such as femininity (and masculinity) and textiles, which by and large remain unstudied to this day (Gale and Kaur 2022).

As Textile design education was initially born out of a tacit craft practice, skills in 'making' and practical techniques were passed down from one generation of students to the next, however the intention and 'why' of the work was rarely questioned (Gale and Kaur 2002; Igoe 2021). This was reenforcing the old stereotypes around the value of women's work, and of craft heritage, and also codified the perception of Textiles as a decorative or constructive realm that existed to create

[2] It should also be clarified that while theoretical development by a man is not an exclusionary criterion, most of the selected frameworks (in addition to being Feminist) are the scholarly work of women, as is the proposed framework. In the spirit of intersectionality, we have selected theories developed by women to highlight and amplify their work, and for their relevance to application within a female-dominated industry and HE sector.

textile products, fabrics, or embellishments to be added to the more important and considered work of others (typically men- architects, product designers or fashion designers) (Parker and Pollock 1981; Parker 1984). Adopting a Feminist lens with which to view textile design enables a critical position that challenges current extractive and unjust systems of design and women's role within them (Lean 2021).

2.2. Transition Design

Transition design is a still-developing field of research and inquiry, and as such has enormous potential to be applied across many disciplines of design, including Textile design. Professor Terry Irwin developed the field of Transition design in 2015 to create a rich, multi-disciplinary approach to solving the world's 'wicked problems' by building on the influential writings of Wolfgang Sachs, Victor Papanek, and more (Irwin 2015; Sachs 1992; Papanek 1995). Transition design theory proposes that the problems facing humanity, and the problems we are already embroiled in, are interconnected, interdependent and always manifest in place and culture-specific ways. Transition design argues that new knowledge and skill sets are required to address these problems, and that their resolution is a strategy for igniting positive, systems-level change and societal transitions toward more sustainable, equitable and desirable long-term futures (Irwin 2015). Transition design uses multiple levels of analysis and knowledge to identify actionable steps toward sustainability and systemic health. Drawing on multiple fields and disciplines, transition design allows a rich, multi-faceted consideration of problems and opportunities for systems intervention.

"Transition design acknowledges that we are living in 'transitional times'. It takes as its central premise the need for societal transitions to more sustainable futures and argues that design has a key role to play in these transitions. It applies an understanding of the interconnectedness of social, economic, political and natural systems to address problems at all levels of spatiotemporal scale in ways that improve quality of life." (Irwin 2015)

Transition design is still in the first phases of practice and application, so many of the initial case studies are still in progress due to long-term futuring. However, Irwin has defined pinpoints of transition design theory and a system of engaging stakeholders through participatory workshops, and these can be adapted and selected to further develop our own framework. Pinpoints of transition design theory can be grouped into three areas of inquiry and intervention: technical, environmental, and cultural. These pinpoints, such as Living Systems Theory, Futuring, Indigenous Wisdom, Cosmopolitan Localism, Everyday Life Discourse, Post-normal Science, Needs and Social Practice Theory, and Alternative Economics help to inform the web of stakeholders inputting into future visions, lending their voice and expertise, and also offer fertile areas of practice to inspire system changes (Irwin 2015; Irwin 2019).

Transition design's acknowledgement of the cultural role of materials and practices in both systemic issues and as a potential site of system healing makes this a relevant framework for application within Textiles, whose connection to human culture and history cannot be divested (Barber 1995; Irwin 2015). As well, the focus on employing and engaging with a wider net of stakeholders and experts in framing both problems and solutions can be seen as a feminist and intersectional praxis, making this theory a valuable contributor to the proposed pedagogy.

2.3. Intersectional Environmentalism

In the early 1990s, civil rights advocate and critical race scholar Kimberlé Crenshaw articulated the theory of intersectionality, which can be defined as the complex and cumulative way in which the effects of multiple forms of discrimination (such as racism, sexism, and classism) combine, overlap, or intersect, especially in the experiences of marginalized individuals or groups (Crenshaw 1991; Thomas 2022). This theory was born out of the American civil rights movement of the 1960s, and the concurrent and subsequent waves of Feminism in America, which often did not include and properly acknowledge the voices and experiences of black women. Crenshaw and other scholars of the intersectional feminist movement defined the mechanisms through which they were often marginalized and ignored even within fights for liberation and justice, despite suffering from multiple axes of oppression (Crenshaw 1991).

The theory of intersectionality can also be applied to the emerging climate crisis, as the same systems of oppression that impact people also degrade the planet (Thomas 2022; Tsui 2024). Intersectional environmentalism is an inclusive approach to environmentalism that advocates for the protection of both people and the planet. It argues that social and environmental justice are intertwined and that environmental actions that disregard this connection are harmful and incomplete and focuses on achieving climate justice by amplifying historically excluded voices and approaching environmental education, policy, and activism with equity, inclusion, and restorative justice in mind (Thomas 2022). People of colour, women, and marginalized communities around the world are bearing the brunt of the climate crisis and environmental injustice (Thomas 2022). Black, Brown, Indigenous, and impoverished people and countries of the Global South – countries that are moving toward becoming industrial and often have a history of colonialism – are facing environmental injustice at alarming rates (Thomas 2022; IPCC 2022). In other words, those least responsible for the climate crisis are bearing the worst impacts of it (IPCC 2022).

Beyond just championing the voices of all stakeholders and everyday citizens, intersectional environmentalism states that traditionally marginalized and oppressed communities such as Indigenous people, people of colour, women, and the economically disadvantaged must actively be at the forefront of any movements for environmental and climate justice (Thomas 2022). Women make up nearly 80% of the textile garment workforce globally, and women's fashion accounts for over 53% of global fashion retail spending, meaning women are a majority in both the workforce and customer base for the textile industry, while holding only 20% of leadership positions within the fashion and textile industries (Labour Behind the Label, no date; FashionUnited, no date; Iglesias 2025). A report by Employment Studies shows that 94% of graduates of fashion and textile design courses are female, and of UK interior design students (a related design discipline), 83% were female (Ball 2010; British Institute of Interior Design 2020). In a Textile design context, an intersectional environmentalist posture acknowledges the oppression of women through a historical under-valuing of their labour, lack of voice in leadership and decision-making, and through the capitalist systems of rapid production and consumption that harm both majority-female textile workers and the planet (Mellor 1997; Gale and Kaur 2002).

2.4. Regenerative Design

Regenerative design is an emerging paradigm that seeks to "regenerate rather than deplete underlying life support systems and resources within socio-ecological wholes" (Mang and Reed 2013). It acts as a baseline for the skills future designers will need to support transformational change within the sector. As an emerging design perspective, there are gaps within the literature, particularly with the practical application of regenerative design within the field of Textiles. However, there are a growing number of examples within architecture and the built environment which employ the term 'net-positive' more broadly, thus widening the scope of application (Ichioka 2021). Shifting to regenerative practices does pose a significant challenge to the design sector, which is already struggling to meet less ambitious 'sustainability' targets such as resource efficiency and supply chain transparency (Mang, Haggard and Regenisis 2016). To shift all design disciplines to regenerative methods of practice will require transformative change in the sector, and in how we prepare and skill up designers (Wahl 2016). The skills required to work as a regenerative designer are aligned with the 'skills for the future of work', which include creative, critical and systems thinking alongside empathy, citizenship and environmental stewardship (Design Council 2025; World Economic Forum 2025; RSA no date). Regenerative Design is also rooted in place, which shifts the homogenous and global focus of the design industry to the local and the community-based (Wahl 2016).

A regenerative future must also be grounded in post-growth principles that divest from current neoliberal capitalism (Ichioka 2021; Raworth 2017). Even though regenerative activities may appear to have a net positive impact on the planet, they cannot be uncritically pursued within a growth-oriented economic framework (Ichioka 2021; Tsui 2024). This prompts a fundamental question for design practice: must we always build or make something new? Such questioning challenges the very foundations of our profession, as we currently lack a framework for recognizing when not to design (Papanek 1997). Exercising the ability to refuse creation, acknowledging that some things should not be built or made, requires considerable courage. Emerging economic theories are also questioning the long-term viability of unchecked capitalism and charting the destructive impact unfettered growth (for some countries and peoples) has had on the planet (Raworth 2017). *Doughnut Economics* theorist and author Kate Raworth proposes alternative economic models, and asks designers to have an active role in shifting mindsets around production and consumption, stating that the first question to be asked in the design process should be 'does it even needs to be built?' (Raworth 2017). A necessary uncoupling of design education from extractive industries and patterns of consumption creates space for new, innovative and collaborative pedagogies (Rowe 2025).

3. From Design Frameworks to Design Pedagogy

As these design frameworks are articulated and considered, we now must begin to understand how these frames inspire and shape pedagogical practices. These emerging design frameworks are values-driven, proposing foundational values that are not just applicable to their content, but also to how they are shared and taught. Hence, such design frameworks can be extrapolated into theories of applied pedagogy. The recent report *Rethinking Innovation* reminds us that "a container is only as strong as the values embodied by its creators" (Ledingham 2024). In our case, the container is that of teaching, and to teach regenerative practice is to embody its values. Cardozo, van den Berg, and Wessel, authors of "The Art of Regenerative Educatorship" (2025), a book addressed to educators, present their full selves, through introductory reflections, stories of their lived experiences, genuine interactions between the authors retold on paper, and closing letters (Cardozo 2025; Ledingham 2024). The format of the book itself teaches the reader about regenerative educatorship, and how living by and personifying these values is in and of itself a pedagogy (Cardozo 2025).

A key role of education should be to challenge conventional notions of progress (Ichioka 2021). The idea of progress is often confounded with technological progress in design disciplines and is imaged as a destructive separation from the past, which prevents us from embracing paradigms of care and of nurture for living beings and place (Ichoka 2021). Such values of care and nurture are thought of as feminine in our Western societies (Ichoka 2012; hooks 1994). This reiterates the importance of a textile design pedagogy grounded in feminism, and intersectional environmentalism.

3.1. Critical Pedagogy

Critical pedagogy is an educational and pedagogical strategy that stresses the need for teachers and students to actively transform knowledge together, rather than simply consume it (hooks 1994). At its most ambitious, the overarching aim of critical pedagogy is to educate students on how to lead a meaningful life, how to hold power and authority accountable, and to develop the skills, knowledge and courage to challenge commonly-held assumptions and to advocate for a more socially just world (hooks 1994; Freire 1970). Critical pedagogy asserts that students can engage with their learning through activating their own agency, and in doing so can actively participate in narrating their experiences through a culture of questioning that opens a dialog between their inner and outer worlds, and accepted forms of self- and social-recognition (hooks 1994). They can use the knowledge they gain both to critique the world in which they live, and when necessary to intervene in socially responsible ways to change it (Freire 1970).

Central to critical pedagogy is shifting the burden of ownership from teachers to students, and articulating the assumed relationships between knowledge, authority, and power (Freire 1970; Freire 2021). Giving students the opportunity to be problem-posers and to engage in a culture of questioning in the classroom foregrounds the critical issue of who has control over the conditions of learning and how specific modes of knowledge, identities and authority are constructed within classroom relationships (hooks 1994). Knowledge is not simply received by students but actively transformed and is open to be challenged. Such an active definition of knowledge is an essential step towards agency, self-representation, and regenerative learning (hooks 1994; Damus 2024).

Particularly in the current social and political climate, education and pedagogical methods often serve as strategies of repression and control; students today have never been more highly-monitored and restricted in freedom of thought and expression, from the homogenizing effects of social media to the ability of phones and personal technology to track movements, clicks, and bodily functions (Tsui 2024; hooks 1994). It is more necessary than ever for education to be a bastion of freedom, and to teach students their capacity for breaking free from oppression of action and thought (hooks 1994).

3.2. Regenerative Pedagogy

Regenerative pedagogy and regenerative education have emerged from critical pedagogy, eco-pedagogy and the teachings of Freire (Lyubansky et al. 2022; Misiaszek 2022). As with regenerative design, regenerative pedagogy recognizes the damage of extractive learning models and explores ways to decolonize and nourish students, staff and the learning environment (Damus 2024). It expands beyond formal education and encourages lifelong learning, but for the purpose of our approach, regenerative pedagogy will be explored within the context of a higher education institution (Cardozo 2025). Regenerative pedagogies remain a novel approach in higher education as they draw upon Living Systems Theory aiming to connect educators to themselves, to nature, and to the community and institution around them (Peavy 2024). It breaks with the histories of extraction that have informed design pedagogies and design education in the past, and recognizes the limitations of existing models such as Sustainable Design and Education for Sustainable Development (ESD) as a pathway to transformational change (Rowe 2025; Redstrom 2017). More examples of academics and scholars adopting regenerative pedagogy are becoming visible, though not yet undertaken on a large scale (Damos 2024; Freire 1970; Macrine 2009).

Regenerative pedagogies highlight an evolving and iterative response to student needs (Damus 2024). Hence, our proposed pedagogy is student-led and student-forward, and includes methods which propose quick action, even where the established pedagogical 'success' of the practice is not yet watertight. While most academics rely on 'expertise' to inform teaching practice, these emerging frameworks allow for co-learning with students, and allows students agency and voice, not just as stakeholders, but as those with an embodied experience of climate catastrophe (Tsui 2024). Allowing the students to shape and drive the conversation, and then in turn the design of curriculum and their course, creates a space to allow for and support intimate and challenging conversation, to share differing worldviews, and then to take action collectively (Irwin 2015; hooks 1994; Damos 2024).
Regenerative pedagogies must also still support the reality of students entering the current world. The challenge for educators lies in accompanying students as they navigate this terrain, moving through the grief of letting go of anticipated futures, while also embracing the excitement of new possibilities that emerge when disciplinary boundaries are released (Bednarek 2024). Caring for students on this journey must also be grounded in an intersectional approach, acknowledging that many students face structural constraints, need to support their families, and may need to currently engage with capitalism, while still giving them the hope and toolset to action radical acts of systemic change in the future (hooks 1994; Ichioka 2021; Tsui 2024).

4. Proposed Regenerative textile design Framework and Discussion

The development of a framework for Textile design practice and pedagogy based on the above theories must push against and challenge established and existing design and Textile design pedagogies. The field of Textile design is well positioned to unify technical-, textile-, and material-related cultural and environmental practices and to pose deep questions about the role and need for both in a regenerative future.

Our call to develop and formalize a framework has come from ongoing experimentation with emerging pedagogies within our curricula and an institutional push to embed 'sustainability' into all curricula at Loughborough University by 2030. As an exercise to both reflexively examine our own practices and to onboard other enthusiastic colleagues, we are now aiming to formalize and iterate a guiding framework. From this exploration and evaluation of existing pedagogies and design theories, some of the key values that emerge are as follows.

Our proposed regenerative Textile design pedagogy must:

- Recognize students and educators as co-creators of knowledge, working in partnership as changemakers to understand our collective agency, and to consolidate belief in the freedom to identify and action our shared visions for the future.
- Empower students and educators to take steps toward climate justice and to engage in individual and collective reflexive practice, which includes acknowledging that each step taken may not be the 'perfect action' and might not be global in scale.
- Honour, centre, and value the role and wisdom of women and other often-overlooked global majority communities in the historical and contemporary commercial practice of textiles, and to not be held back by limitations placed on the discipline rooted in sexism and gender stereotype.
- Equip students with the agile skills needed for a future textiles industry, which must engage with regenerative design principles to survive and thrive.
- Deepen the connection of humans and more-than-humans to textiles and material, recognize complexity and interconnectedness, and the crucial role placed-based material knowledge, adaptation, and sustainable material literacy will play in systemic healing.
- Making and un-making: have the courage to challenge business (and education) as usual.
- Recognize the importance of personal wellbeing in both students and staff for a flourishing educational ecosystem.

5. Next Steps

Design education must decouple from its origins, or potentially must reclaim them again, as in its purest definition to design is a profoundly human thing; a reflection of the innate desire to "change existing situations into preferred ones" (Simon 1982). However, with the codification of design as a profession came the unfortunate coupling with capital gains and a mostly unchecked exponential growth curve of commercially available goods and services, all while espousing design's role in society as identifying and meeting human needs (Papanek 1995). It's hard to believe that nearly 40 years on from Papanek writing in *Design for the Real World* that "Design, if it is to be ecologically responsible and socially responsive, must be revolutionary and radical", and we are still trying to find ways to embody this ethos (Papanek 1985).

The impending climate collapse has put a sharper point on these conversations, and new theorists and champions are emerging, most notably intersectional feminist and climate justice youth activists, who are speaking to the needs of people and planet from their less-then-rosy lived experiences. Those of us old enough to be working in higher education, old enough to be developing curriculums and theories for pedagogy, are lucky enough to still have memories of unspoiled childhoods and experiences that aren't coloured by the knowledge of an ecological and societal disaster looming on the horizon. The most radical and critical act of a pedagogy must be to first listen to the students and allow them to shape the education and the tools they will wield in the future. We can no longer straddle a line of perpetuating old ideologies and old ways of design thinking and practice and instead must embrace the uncertainty in the times ahead. Emergent theories and frameworks such as critical pedagogy, regenerative pedagogy, and our own emerging regenerative Textile design pedagogy shift the frame and the role of both students and educators.

The next steps for our proposed framework are to expand our theories into a series of actionable steps and guiding principles. These will now be co-developed with students in a series of stakeholder workshops, as the pedagogy is for us all, and must acknowledge all of our worldviews, aims, areas of expertise, and hopes for our short and long-term futures. These co-creation workshops will engage with a wide range of stakeholders and the resulting *Framework 1.0* will be immediately actioned within our Textile design programme. Feedback will be intentionally and continually gathered and used to inform iterations and adaptations of the pedagogy so that it may continue to meet the needs of the students and those 'teaching'. Our proposed regenerative Textile design pedagogy is not intended to be prescriptive, but rather to be an embodied practice of regenerating ourselves, our teaching, our curriculums, and our futures. And most crucially, as educators we must remember that "to change everything, we need everyone" (Ichioka 2021).

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Co-designing Plant-based Reusable Theatre Caps with NHS Scotland

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Abstract

This plant-based reusable theatre cap project, developed in collaboration with NHS Scotland, forms part of the AHRC-funded Green Transition Ecosystem Hub, **Design HOPES** (Healthy Organizations in a Place-based Ecosystem, Scotland). This transdisciplinary initiative applies design-led innovation to address health service challenges while supporting net-zero sustainability goals. Recognizing that healthcare is a major global emitter of greenhouse gases, this project seeks to reduce waste from disposable operating theatre consumables and improve communication among staff wearing PPE. By co-designing reusable, plant-based theatre caps with NHS Scotland theatre staff, the project aims to enhance comfort, functionality, and environmental sustainability. In 2023, an estimated 110 million disposable caps were sent to landfill worldwide, with around 2.5 million used annually in National Health Service Scotland hospitals alone. The reusable alternatives presented here offer a scalable solution to reduce waste and carbon emissions, contributing to a more sustainable healthcare system and improved working conditions for theatre staff.

Keywords: Co-design, healthcare, net zero, reusable theatre caps, sustainability.

Introduction

This plant-based reusable theatre cap project, in collaboration with NHS Scotland, is part of a larger AHRC-funded Green Transition Ecosystem Hub entitled Design HOPES (Healthy Organizations in a Place-based Ecosystem, Scotland) - a transdisciplinary research project that aims to exploit the potential of design-led thinking, making, and acting to innovate and tackle multifaceted health delivery challenges to meet urgent net zero goals for a sustainable health and social care system. The effects of climate change on health will affect most populations and put the health and wellbeing of billions of people at increased risk (Costello et al. 2009). To put this into perspective, if healthcare were a country, it would be the fifth-largest emitter of greenhouse gases on the planet, according to Health Care Without Harm. The project aims to reduce NHS Scotland operating theatre consumables' waste and address communication barriers between staff wearing full theatre PPE. Working closely with NHS Scotland theatre staff, this paper will describe how we have co-designed a range of reusable plant-based theatre cap options that reduce theatre waste whilst improving staff communication and comfort. It is estimated that in 2023 a minimum of 110 557 119 (over one hundred and ten million) disposable theatre caps ended up in landfill (Costello et al. 2009). In Scotland alone, around 2.5 million single-use disposable theatre caps were used across Scottish hospitals in one year between September 2022 and September 2023 (Centre for Sustainable Delivery/NHS Scotland National Green Theatres Programme 2024). The caps will help to significantly reduce the environmental impact of medical waste.

Context

The UK's National Health Service (NHS) is responsible for approximately 4% of the country's carbon emissions, and over 7% of the economy. As such, it has a vital role to play in meeting the net zero targets set under the Climate Change Act "Delivering a 'Net Zero' National Health Service" (NHS England and NHS Improvement 2021). Design HOPES' focus, NHS Scotland, has set its own ambitious targets for net zero to 2040. As a significant contributor to meeting this 2040 target, NHS Scotland offers considerable design-led opportunities for a green transition. Design HOPES, working closely with NHS Scotland and other relevant stakeholders, has the potential to scale and amplify successful design-led innovations to wider NHS UK contexts and beyond through an international coalition of over 50 countries who have committed to developing low-carbon health Systems (NHS Scotland, Climate Emergency & Sustainability Strategy 2022 to 2026, 2022).

Design-led research in health and social care contexts has changed in recent years, shifting from a focus based largely on economic growth towards one of wider social and environmental issues that highlight more design-led systemic approaches. Many design researchers including several members of Design HOPES are involved in the sustainable design of interventions such as innovative products, services and systems that positively impact on the environment, health and healthcare, promote dignity and enhance quality of life, and action change in a range of settings (Robertson et al. 2022; Bruce and Baxter 2008; Rodgers 2021).

Recent research into health service design, delivery and improvement has presented compelling evidence that a design-led systems approach to addressing health delivery challenges may lead to significant improvements in both patient and service outcomes (Komashie et al. 2021). At the same time, the UK Design Council Systemic Design Framework (Design Council 2021) offers guidance to designers, collaborating disciplines and sectors to create meaningful change. Design HOPES, part of Future Observatory, the Design Museum's national research programme for the green transition funded by the Arts and Humanities Research Council, which is part of UK Research and Innovation, is a collaborative, design-led green transition ecosystem hub that comprises five Scottish Universities (Strathclyde, Dundee, Heriot-Watt, Abertay, and Edinburgh), health boards across Scotland's National Health Service (NHS), the third sector (charities, social enterprises, co-operatives etc.) and organizations from the design economy. The climate emergency is a health emergency and in response Design HOPES aims to exploit the potential of design-led thinking, making and acting to innovate and tackle multifaceted health and social care delivery challenges by creating, prototyping, and testing new products, services, tools, and systems needed for NHS Scotland to meet, and move beyond, urgent net zero goals.

In other work (Rodgers et al. 2025), we have highlighted the pluralistic nature of contemporary design research and how it comprises a rich and diverse range of methods, approaches, and tools that are inclusive, explorative, creative, critical and engender inquisitive attitudes (Rodgers and Yee 2023). This pluralistic design research terrain includes many perspectives and voices, which means many different ways of speaking. Ranulph Glanville reminds us that variety is crucial and we should be careful to guard different ways of thinking, exploring and writing about design and research, and we should value this variety while following our own design research journeys (Glanville 2015).

Design HOPES Projects

The plant-based reusable theatre caps are just one of several ongoing Design HOPES projects, each highlighting powerful design-led thinking, making, and acting methods and tools used (Image 1). These projects illustrate how, using a design-led and rich collaborative approach, one can re-imagine the design and delivery of future health and social care provision in ways that will deliver environmental sustainability. Design HOPES projects sit at the intersections of design, health and wellbeing addressing complex net zero challenges with an emphasis on inclusive, equitable, and sustainable design-led interventions. These projects encompass diverse interventions across and beyond conventional design boundaries such as architecture, product design, and textile design providing outcomes that demonstrate the impact of design-led research on real-world net zero issues.

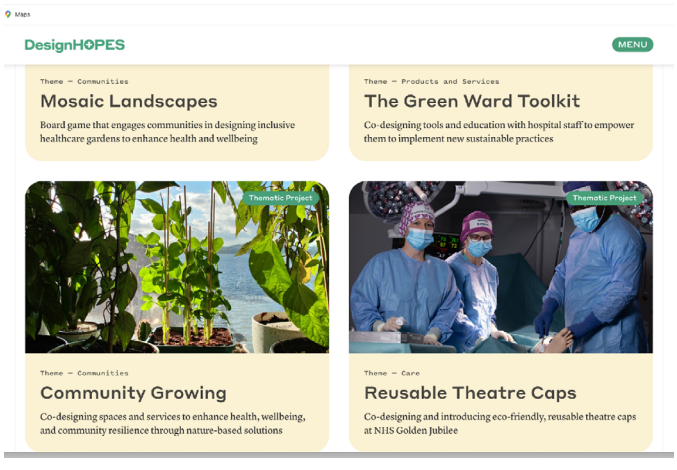

Image 1: Selection of Design HOPES' Projects.

These ongoing Design HOPES projects have been selected through a rigorous combination of stakeholder involvement where NHS Scotland, Scottish Government, and others working with the core Design HOPES team have explored, analyzed what might work, discussed different perspectives from conventional ways of doing things (including from those that have historically been marginalized), reframed problems and issues to support the transition to a regenerative world in a series of local co-design workshops and through more formal design sprints.

A design sprint is a time-constrained activity that allows team members to work intensively in testing objectives, pre-conceived ideas and stakeholder requirements in relation to design problems, and in contexts where action and design research are being undertaken simultaneously that can accelerate the rapid production of prototypes, models and demonstrators that help develop design thinking, making, and acting (Keijzer-Broers and de Reuver 2016). Design HOPES has held four design sprints thus far, based on the UK Design Council's Systemic Design Framework (Design Council 2021), that have taken place with different themes, moving from activities dedicated to problem exploration to design-led realisation, intervention, and impact as follows:

- **Explore**: Study what is happening and actively draw in perspectives that are different from conventional ones, including those which may have been overlooked.
- **Reframe**: Moving to a regenerative world means breaking out of our current way of thinking. We must reframe the challenges in different ways to achieve new ideas.
- **Create**: Generate different actions and ideas that help people reimagine what might be possible.
- **Catalyze**: Design is about making things. It shows people what a new future vision might look and feel like. It is important here to make and test how things work and to explore how they connect with other designed interventions.

The design sprints were formatted in such a way that the Design HOPES' team was able to work within and across different themes, and appropriate expert input could be integrated within the sessions. This facilitated a sharing of knowledge, methods and approaches to tackle the issues that emerged. In short, reframing the problems facing NHS Scotland in different ways to deliver new ideas.

Design HOPES' projects are all inspired and organized around the NHS Scotland/Scottish Government Climate Emergency and Sustainability Strategy core themes (Scottish Government 2022). The wider Design HOPES team comprises a rich interdisciplinary mix of individuals with significant expertise in design and making, co-creation, health and social care, allied with professionals with a sustainability remit, and businesses working in the design economy. The projects in development will deliver tangible outcomes such as new innovative products, services, and policies (e.g., sustainable theatre consumable products, clothing, waste services, etc.).

Methods

Central to Design HOPES is its co-design approach, with the voice of NHS Scotland staff core to the definition of problems and the generation of appropriate design-led interventions. By including NHS Scotland staff and other relevant stakeholders at the design sprints, and central in the design research activities of projects, some clear characteristics emerged. Firstly, time and resource pressures were a primary concern and a barrier to change. Health and social care services are increasingly required to do more with less (The Health Foundation 2022), meaning that although staff would like to transition towards more effective working methods, they lack the capacity to develop and implement new models. Another major challenge we have encountered is the interaction of a wide range of stakeholders with complex dynamics. The NHS is the largest employer in Scotland with nearly 200 000 people and is a deeply hierarchical organization with distinctly defined job roles. This, combined with the fact that it serves the breadth of the national population (not only patients but supporting families and visitors) means that there are a huge number of competing incentives and agendas in delivery of its overall goals that are not easily tracked by performance management systems (Ojiako et al. 2023). Nevertheless, there remains strong incentives towards health and wellbeing amongst staff. Individuals who work in healthcare have a tendency towards high levels of empathy and are motivated to help individuals (Moudatsou 2020). While this is a powerful force to be harnessed, it can lead to high levels of stress and disillusionment when it is not possible to deliver the services expected (May 2024; Wilkinson 2017). There is also a historical and ongoing conflict between regulations and desire for change. The rigid regulatory environment to protect hygiene and safety, and the bureaucratic culture that has emerged in the wake of this, means that change can be difficult to implement even where opportunities and benefits are clear (Arora 2021).

The conversations that have emerged in Design HOPES projects have helped to embed the overall project ethos, and have facilitated the development of strong bonds between NHS Scotland staff and project partners. The design-led methods and tools that have been co-created have helped deliver a range of benefits that are focussed on increased adoption of circular, sustainable innovative design solutions (i.e., products, services, strategies and policies) and health system transformations. The Design HOPES' projects are now beginning to generate social, cultural environmental and economic impact assessed using a quadruple bottom line framework developed in earlier research (Rodgers 2024).

This innovative work started by undertaking a series of activities that (1) aimed to understand the current use of disposable single-use theatre caps and (2) to co-design and develop a sustainable reusable theatre cap. Initially we conducted a series of exploratory co-design workshops with NHS Scotland theatre staff to ascertain what happens in NHS Scotland operating theatres, determine the key issues, and co-develop with NHS Scotland theatre staff a bold and innovative reusable and sustainable alternative to the current single-use disposable cap.

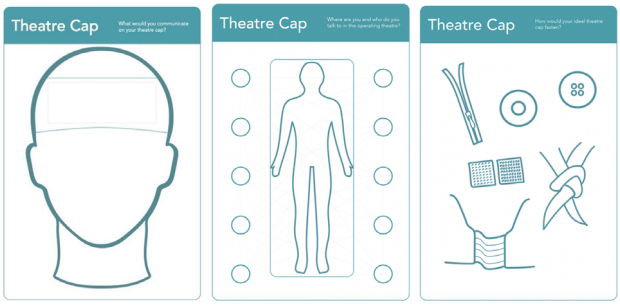

Image 2: Reusable Theatre Caps Design Probe.

At this stage, we asked via a design probe (Image 2), semi-structured interviews, and a series of co-design paper prototyping workshops (Image 3) the following questions:

- What barriers are there for you in using reusable theatre caps?
- What would you like to communicate on your theatre cap?
- What material would you like your theatre cap made from?
- How many theatre caps (on average) do you use each day?
- What else you would like to say about theatre caps?

Image 3: Paper Prototyping Reusable Theatre Caps. Credit: Authors

At the end of the first round of co-design workshops with NHS Scotland staff, our explorations revealed a number of key insights related to what happens in theatre settings as well as some of the significant issues involved. In these co-design sessions, we actively drew on perspectives from key stakeholders including surgeons, anaesthetists, and nurses and others that might have been marginalized historically. The responses highlighted clearly a number of features that the theatre staff wished to see in any new reusable theatre cap:

- Breathable; hair-friendly; easily washed; soft; comfortable
- Should evoke friendliness; should clearly show first name and job role
- Should be friendly and welcoming in appearance; available in different colours

After gathering different types of knowledge and feedback from a range of NHS Scotland theatre staff with different perspectives, we started making a series of first series prototypes (Image 4) that would meet the staff's initial requirements. Specific feedback on our first series of reusable theatre cap prototypes included:

- "The square caps are uncomfortable... more rounding on caps needed";
- "Oscar the jersey hat is the best material!";
- "The new theatre cap is comfortable, breathable and fits perfectly over hair clips... it fits securely and there is no worry of it falling off my head";
- "The drawstring to ensure good fit is good";
- "I like the feel and fit of the Skye (woven) hat with ties, and also the Oscar hat with ties"; "having a choice of sizes is good";
- "I prefer the tie at the back due to different hairstyles";
- "Not keen on the square shape - perhaps sew corners more rounded";
- "Nice feel of fabric, light and airy."

Image 4: Reusable Theatre Caps - First Series of Prototypes. Credit: Authors

After several months of further iterative design development, most notably involving zero waste pattern layout and cutting, digital printing tests, textile and laundry tests, and wearability and fit testing, we returned to NHS Scotland staff with a range of second series reusable theatre cap prototypes (Image 5). The insights from this round of user-testing with NHS Scotland staff included the following:

- NHS Scotland staff preferred the softer fabric made from cellulosic fibre material
- Staff liked the tie fastening at the back
- Staff liked the idea of S, M and L sizes

Image 5: Reusable Theatre Caps - Second Series of Prototypes. Credit: Authors

Following extensive feedback on the first and second series of prototypes received during the co-design workshops, further prototypes were developed focusing on design, style and fit to address the following comments:

- "Unique personalization is important"
- "Solid colours as well as patterns is good"
- "Good for identifying each individual"
- "Colourful, easy to identify staff"
- "I would like the roles to be added... this is beneficial for both patients and staff. Especially in emergencies!"
- "Names and roles can help as it gets confusing. Will be more helpful for patients also."

To date, the Design HOPES reusable theatre cap team have facilitated five co-design workshops that have progressed through the Design Council's Systemic Design Framework four iterative stages - explore, reframe, create, and catalyze (Design Council 2021). The team presented this work to the Scottish Government Cabinet Secretary for Health during his visit to NHS Golden Jubilee hospital on 25 September 2024. Furthermore, the reusable theatre caps have been exhibited as part of a Design HOPES Work-in-Progress exhibition at the V&A Dundee (6 December 2024 to 23 February 2025) and more recently at the Future Observatory: Tools for Transition exhibition[1] at the Design Museum, London (12 September 2025 to August 2026) (Image 6).

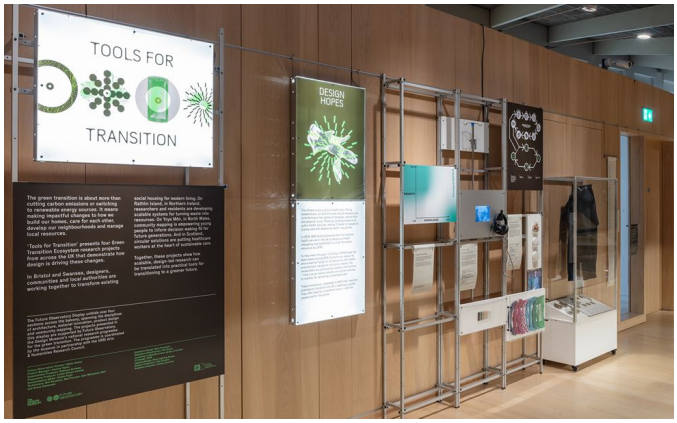

Image 6: Tools for Transition Exhibition - Design HOPES section. Credit: Luke Hayes

1 https://designmuseum.org/exhibitions/future-observatory-tools-for-transition

Results

The Design HOPES plant-based reusable theatre caps deliver significant benefits to NHS Scotland in three important ways, namely (i) environmental, (ii) economic, and (iii) patient safety:

1. **Eliminates single-use disposable theatre caps.** In 2023, it was estimated that a minimum of 110 557 119 (one hundred and ten million) disposable theatre hats ended up in landfill. The Design HOPES plant-based reusable theatre hats make a significant impact on reducing total landfill waste. On average a UK hospital disposes of around 100 000 single-use disposable hats every year (Eco Ninjas 2025). Changing away from single-use disposable theatre hats to our plant-based reusable theatre hats eliminates disposable items from going to landfill across NHS Scotland.
2. **Reusable theatre caps save money.** Studies show that reusable theatre caps are more cost effective as they last longer (approximately 3 years with regular washing) than their single-use disposable competitors (Billingsley 2022). Moreover, it is reported that whilst 1 443 264 single-use disposable caps have to be manufactured every year, only around 10 459 reusable theatre caps have to be produced every three years (Billingsley 2022).
3. **Reusable theatre caps increase patient safety and overall efficacy.** Studies show that reusable theatre caps allow less contaminants into the operating room atmosphere than disposable ones, potentially reducing surgical site infections (SSIs) (Markel et al. 2017). It has also been shown that reusable theatre caps have no association to risk of SSI in general surgery (Haskins et al. 2017). A significant feature of the Design HOPES' reusable theatre caps is their personalization (name and role of the NHS Scotland staff member prominently displayed at front). Studies report that between 30 to 50% of people forget their colleagues' names after surgical briefings (Birnbach 2017; Burton 2018), and that teams work better when they know the names and roles of other members (Bobb 2018; Leonard 2004).

Image 7: STV News Feature on the Reusable Theatre Caps. Credit: Marsaili McGrath

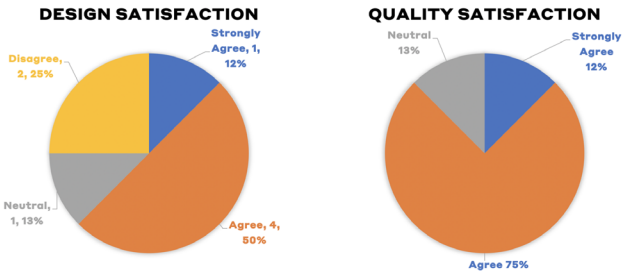

Figure 1: Design HOPES Reusable Theatre Caps User Testing Initial Results.

In addition to the clear environmental, economic, and patient safety benefits of these new plant-based reusable theatre caps, this research project has secured significant traction across UK media channels with over 200 coverage hits to date. Highlights include print coverage in a number of UK national newspapers including *The Glasgow Herald* (Martin 2025), *The Scotsman* (McDougall 2025), and *The Daily Telegraph* (Daily Telegraph Reporter 2025), broadcast television coverage e.g., STV News (Image 7), regional UK coverage (*i.e.*, London Evening Standard, Glasgow Evening Times), key online sites like MSN, Yahoo, and current affairs titles such as *Perspective* magazine and *Health Industry Leaders* magazine. Future work planned includes further testing of the plant-based reusable theatre caps including laundry and biodegradation tests, extensive user-testing across NHS Scotland health boards, and the development of a start-up Community Interest Company (CIC) that will design and manufacture the Design HOPES plant-based reusable theatre caps in Scotland.

We have recently commenced user testing with approximately 250 NHS Scotland theatre staff including surgeons, anaesthetists, and nurses. Early results indicate that NHS Scotland staff are delighted with the aesthetic and material qualities of their reusable theatre caps. Moreover, users have responded extremely positively about the comfort of the reusable theatre cap material against the skin, which was a key driver in the design and development of the plant-based reusable theatre caps. Users have raised some issues with the fit of their theatre cap, which appears to be related to the ties at the back. Overall, however, NHS Scotland staff have reported high levels of satisfaction with the design and quality of their reusable theatre caps (Figure 1).

Discussion

The Design HOPES' project continues to exploit the power of design-led research for net zero challenges in innovative and collaborative ways. Design HOPES' work with NHS Scotland, industry partners, and other relevant stakeholders continues to utilize a diverse set of innovative co-design and co-production methods and tools to develop novel and useful prototypes including new products, services, and systems.

Design HOPES' researchers will continue to collaborate closely with key clinical and operational figures across NHS Scotland health boards, building trust through co-design workshops, design sprints, and sustained specific projects. Doing so over the last two-and-a-half years has been fundamental in creating an environment where ideas can be shared, discussed, and critiqued freely and openly. With this foundational trust established, various design-led research tools have provided a variety of means to closely observe, interrogate and understand user (NHS Scotland staff) behaviour in order to respond to contextual needs. This is particularly important where values and beliefs are not easily articulated or motivations for behaviours not readily apparent (Krippendorff 2004). Across the Design HOPES' project, we have seen design-led tools such as pop-up exhibitions, interactive games, cultural probes and future scenarios being deployed to help bring clarity to the specific requirements of NHS Scotland stakeholder groups and individuals. As a precursor to these collaborations, we have secured appropriate ethics approval for NHS Scotland engagement in all design collaborations. In addition to the legal and ethical necessity of this, it has been an important activity in highlighting procedural and cultural issues associated with the organizations involved. The necessity to, for example, focus on staff rather than patient engagement has dictated the format and configuration of the design tools employed.

The act of design is a creative, playful and engaging process, and when delivered effectively can allow designers and non-designers to collaborate fruitfully in the generation of new solutions that are innovative but grounded by expertise in the relevant context (Steen 2013). Most of us find creative involvement to be rewarding (Bujacz et al. 2016), and co-design activities, with designers acting as facilitators, have mobilized and motivated clinicians including surgeons, anaesthetists, and nurses, care-givers, technicians, administrators and other relevant stakeholders to generate new perspectives on existing problems. Across the Design HOPES' project, we have created design-led methods and tools to meet the demands of the NHS Scotland workforce including online formats for remote contribution, timings to accommodate shift working, acknowledgement of regulatory and procedural constraints etc. Where scepticism has arisen, and individuals have been reluctant or unwilling to engage, we have found the provision of visual material and tangible prototypical artefacts critical in stimulating engagement. We have made extensive use of quick-and-dirty and low fidelity models and prototypes that make design possibilities tangible and aid effective communication for those both directly involved in, and those observing, the design process. This has allowed the team to iteratively design, make, test and evolve solutions in conjunction with NHS Scotland staff and to highlight the possibilities to NHS Scotland and Scottish Government policy makers. Together, these functions embody how design has been utilized to help all types of healthcare professionals, from frontline medical staff to supporting managers, recognize where issues lie, imagine new ways of working, and participate in their design and implementation.

Acknowledgements

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Co-designing Sustainable Scrubs with NHS Scotland: Material Futures and Net-zero Healthcare Design

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Abstract

As global healthcare systems confront the climate emergency, design emerges as a strategic tool for systemic transformation. This paper presents a design-led initiative within NHS Scotland to reimagine hospital scrubs - ubiquitous yet overlooked garments - through co-design, material innovation, and circular systems thinking. Drawing on NHS Scotland's Climate Emergency and Sustainability Strategy, the project explores how redesigning scrubs can reduce carbon emissions, enhance workplace dignity, and challenge procurement norms. Through participatory methods, including a co-design pop-up at Golden Jubilee Hospital, the research uncovers critical issues in fit, identity, and material sustainability. By proposing plant-based alternatives and ethical procurement models, this work positions scrubs as a strategic entry point for net-zero healthcare, demonstrating how design can catalyze cultural, environmental, and institutional change.

Keywords: Co-design, design-for-health, NHS Scotland, scrubs.

Introduction

With responsibility for approximately 4% of the UK's total carbon emissions and contributing over 7% to the national economy, the National Health Service (NHS) plays a pivotal role in achieving the UK's legally binding net zero targets under the Climate Change Act (NHS England 2020). Within this context, NHS Scotland has committed to becoming a net zero greenhouse gas emissions health service by 2040, aligning with the Scottish Government's broader climate emergency response (NHS Scotland 2022). This ambitious target positions NHS Scotland as a critical actor in the nation's green transition, offering fertile ground for design-led innovation to support systemic change.

Design HOPES, a collaborative research initiative working closely with NHS Scotland and other stakeholders, exemplifies how design research can contribute to sustainable transformation. By embedding design thinking into healthcare systems, the project aims to scale successful innovations across NHS UK and internationally, aligning with the commitments of over 50 countries that have pledged to develop low-carbon health systems (Oliveira et al. 2021; NHS England 2020).

One such innovation focuses on a poorly understood but impactful element of healthcare infrastructure: hospital scrubs. Worn daily by NHS Scotland's nearly 200 000 employees, scrubs represent a significant cost in terms of procurement, laundering, and environmental impact. Despite persistent concerns over comfort, fit, sustainability, and user experience, the design of NHS scrubs has remained largely unchanged for over two decades (Morris & Murray 2021). This paper presents a design-led research project that explores and critically examines hospital scrubs through co-design methodologies, engaging healthcare workers, laundry services, and procurement teams to understand the material and political impact of scrubs within the design-for-net-zero agenda (Ceschin & Gaziulusoy 2016; Lennox, Maher & Reed 2018). As healthcare systems globally grapple with the dual challenges of climate change and resource constraints, such targeted, scalable interventions demonstrate how design can act as a catalyst for sustainable transformation.

NHS Scrubs: Garment History and Context

Before the founding of the National Health Service in 1948, healthcare in Britain was a patchwork of private, voluntary, and municipal institutions (Webster 2002). Nurses, often trained in religious or charitable settings, were expected to source and maintain their own uniforms, which were imbued with both professional symbolism and personal identity. Archival materials from the Royal College of Nursing show that garments were often handmade or tailored, with advertisements for patterns and fabrics appearing in monthly bulletins. These uniforms, typically long dresses with aprons, starched collars, and caps, were not only functional but also deeply gendered, reinforcing the image of the nurse as disciplined, modest, and maternal (Summers 1988).

Image 1: Historic example of a nursing uniform, (left) a precursor to modern scrub garments (right). Credit: Open source images

Scrubs emerged as a distinct form of clinical attire in the 1970s, replacing traditional nursing uniforms with garments designed for sterility, ease of laundering, and functional simplicity (Jones 2010). NHS scrubs typically consist of a V-neck top with patch pockets and loose-fitting trousers with a drawstring waist, available in a range of colours – light blue and green being common for theatre and non-theatre use. These garments are worn alongside other personal protective equipment (PPE), such as surgical gowns and facemasks, forming a critical layer of infection control within clinical environments (Image 1).

The rise of global mass production in the 1980s marked a turning point in the design and supply of healthcare garments. Disposability became a key design feature, driven by the availability of synthetic materials like polyester and the economic efficiencies of offshore manufacturing. As Gregson et al. (2007) argue, this shift reflected broader trends in consumer culture and supply chain globalization, where low-cost labour and rapid production cycles enabled the proliferation of single-use textiles across sectors, including within healthcare.

Today, NHS Scotland sources its scrubs from MPI, a multinational supplier with manufacturing operations in Canada, Portugal, and China. Scrubs are stocked in hospital wards in various sizes, allowing staff to select garments that fit appropriately. However, ongoing pressures to reduce NHS costs have led to a decline in garment quality, with implications for durability, comfort, and sustainability (Jones 2010). These issues are central to this paper's inquiry, which explores how design-led innovation can address the limitations and contribute to structural and political improvement.

Situating this discussion within the design for sustainability and (more broadly) net-zero frameworks (see Ceschin & Gaziulusoy 2019) reveals the urgent need to rethink healthcare textiles as part of a broader strategy for climate resilience. The NHS's net zero commitments require systemic interventions across procurement, waste management, and material innovation. Scrubs, as high-volume, high-turnover garments, represent a significant opportunity for carbon reduction. Their lifecycle, from raw material extraction and manufacturing to laundering and disposal, embodies many of the environmental challenges facing healthcare systems today (Zadeh et al. 2016).

Design-led approaches offer a pathway to reimagine scrubs not only as functional garments but as strategic assets in the transition to low-carbon healthcare. By applying principles of circular design, such as material substitution, modularity, and end-of-life planning, designers can reduce the environmental footprint of scrubs while enhancing user experience (Ceschin & Gaziulusoy, ibid; Moorhouse & Moorhouse 2017). Co-design methodologies, which engage healthcare workers, laundry services, and procurement teams, ensure that new garments meet clinical needs while reflecting values of dignity, inclusion, and sustainability (Calvo & De Rosa 2017; Webb et al. 2018).

Moreover, the redesign of scrubs aligns with the NHS's broader commitment to ethical procurement and social value, as outlined in its net zero strategy. By sourcing plant-based, biodegradable materials and exploring local manufacturing options, the initiative contributes to reducing 'Scope 3' emissions (those associated with supply chains) which account for the majority of the NHS's carbon footprint (NHS England 2020). In this way, scrubs become more than garments; they become a lens through which to examine the intersection of design, climate action, and healthcare ethics and politics. As healthcare systems globally grapple with the dual pressures of climate change and resource scarcity, targeted interventions like this demonstrate how design can catalyze sustainable transformation at scale.

Design, Dignity, and the Politics of Uniformity

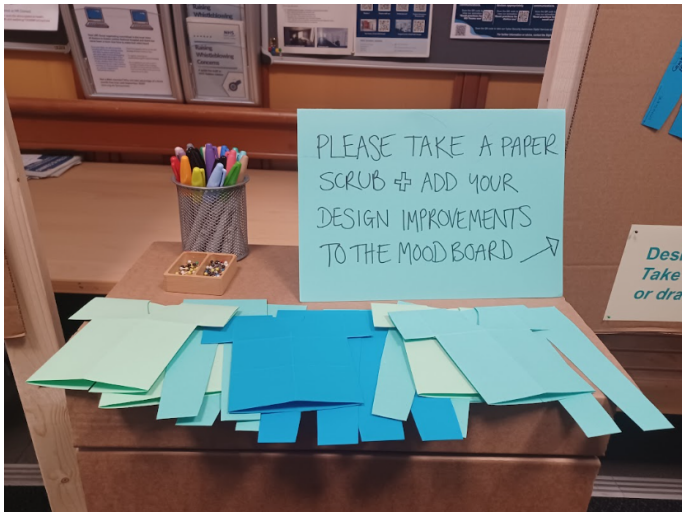
Uniforms are never neutral. They carry symbolic meanings, institutional values, and embedded power dynamics. In the NHS, scrubs have evolved into a contested site where tensions between standardisation and individuality, efficiency and care, and cost and quality are continuously negotiated (Klein 2010). As Blustein and Allan (2024) argue, workplace dignity encompasses more than wages or working conditions - it includes how workers are seen, valued, and represented through the materials and symbols of their labour. Scrubs, therefore, are not merely functional garments; they are cultural artefacts that reflect the ethos of the healthcare system and the lived experiences of its workforce.

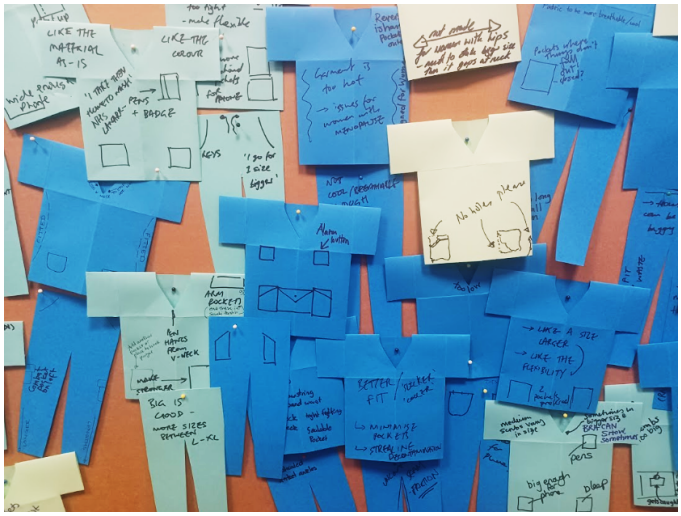
This paper contends that the current model of NHS scrub provision - characterized by low-cost procurement, minimal design input, and significant environmental externalities - is no longer fit for purpose. Instead, we propose a design-led reimagining of scrubs that centres on co-design, sustainability, and dignity. By engaging healthcare workers in the design process and exploring plant-based, biodegradable alternatives, the initiative seeks to develop garments that are ecologically responsible and emotionally resonant (work by Jonathan Chapman (2005) explored this in his framework of 'emotionally durable design' alongside numerous 'design for emotion' studies, see Ho and Siu (2012) for an overview).

This approach aligns with broader movements in design for social innovation and public sector design, which position design as a transformative tool for reconfiguring systems, amplifying marginal voices, and imagining alternative futures. Ezio Manzini (2015) describes design for social innovation as a process in which both expert and non-expert designers collaborate to create solutions that are meaningful, sustainable, and context-sensitive. Similarly, Christian Bason (2017) argues that public sector design enables managers and institutions to engage with complexity, challenge assumptions, and co-produce public value through human-centred governance. In this sense, the redesign of NHS scrubs is not a superficial intervention but a strategic entry point into rethinking how the NHS can embody its values of care, equity, and sustainability. It reflects a shift from transactional procurement to relational design - where garments are not just supplied but co-created with those who wear them generating a more ethical and equitable political structure within the organization (see Meléndez and Martinez-Cosio (2019) for a study exploring this in a different context and also Ní Shé and Harrison (2021) who highlight the potential for 'unintended consequences' in co-design methods where it is unclear if co-design is the best approach to achieve specific project goals).

Understanding the Issues: Co-design Pop-up

Working directly with the NHS Golden Jubilee hospital in Glasgow, we set up a pop-up display exhibition within the hospital premises to collect data about scrubs. Participants were encouraged to take a set of small paper scrubs and share their thoughts on the current design and suggestions on how the current garments could be improved. The pop-up display had a 'walk-in' format so people could interact with ease. Once a participant had commented or drawn on to a paper scrub, it was pinned on the board, creating an open collage that could be added to (Image 2).





Images 2 and 3: Co-design pop-up at the Golden Jubilee National Hospital.

Results

We collected over 90 contributions where participants highlighted their key issues. Most decided to include small sketches with annotations (Image 3). The data collected comprised a rich repository of qualitative data containing key opinions, feelings, desires and design ideas.

Image 4: Selection of paper scrub tops and bottoms co-design contributions.

Our analysis reveals several key design-related concerns in the current provision of healthcare scrubs. Pockets emerged as a prominent issue, with numerous participants reporting poor construction and expressing a need for additional storage. Gender-specific feedback also surfaced, particularly regarding the neckline: many female nurses reported feeling exposed due to the deep V-neck design. Challenges related to size and fit were frequently cited, with respondents struggling to find appropriately fitting garments and encountering inconsistent sizing across products. Furthermore, a notable number of participants expressed a lack of personal or institutional identity in their scrubs, voicing a preference for features such as NHS logos or personalised identifiers indicating name and role.

These findings suggest that the matrix of design shortcomings reflects a broader politics of un-care at both institutional and governmental levels. This is evident not only in the lived experience and dignity of healthcare staff but also in the material and environmental dimensions of the garments themselves. While care workers are expected to perform demanding roles with precision and resilience, the clothing they are provided with symbolically embodies the systemic failures of the environments in which they operate.

Scrubs and Net-zero Politics

Even a partial analysis using co-design methods reveals a litany of issues with the current designs. The question that is presented to us next is; how do these problems interact of the politics of net-zero design? Critically, this is where considering materiality and system design can be instructive. Scrubs mostly are made from polyester or polycotton blends: fossil-fuel-derived materials that are energy-intensive to produce, non-biodegradable, and prone to shedding microplastics during laundering. These microplastics contribute to aquatic pollution and pose risks to human health through inhalation and ingestion (Plastic Soup Foundation 2022).

The laundering process compounds these issues. NHS laundry systems operate at high temperatures (80–180°C) and rely on large volumes of water, energy, and chemicals. Frequent washing of low-durability garments accelerates textile degradation and increases replacement rates, contributing to waste and emissions. At end-of-life, many scrubs are incinerated, releasing greenhouse gases and undermining NHS net-zero ambitions. In the UK, nearly half of all used textiles are discarded in residual waste streams, with 84% incinerated and 11% landfilled (see WRAP's (2024) report and Sussex Community NHS Foundation Trust, (2024)).

Despite these impacts, scrubs have largely escaped scrutiny in NHS sustainability strategies. This oversight reflects a broader challenge in climate policy: the prioritization of infrastructural and technological interventions over everyday material systems. As Fletcher and Tham (2019) argue, sustainability must be understood not only as a technical issue but as a cultural and systemic one; embedded in the routines, garments, and tools of daily life.

Design-led alternatives offer a pathway to reduce emissions across the scrub lifecycle. Plant-based, biodegradable materials such as hemp, lyocell, flax, and organic cotton present viable options. These fibres decompose naturally, reduce microplastic pollution, and require fewer resources during cultivation and processing (Karimah et al. 2021). Flax, the fibre that makes linen, the growing and processing of which was once a large industry in the UK (Image 4) entered terminal decline in the 1960s, could be a key future net-zero fibre. Interestingly, there are various efforts across the UK including Fantasy Fibre Mill in east-Scotland and Flaxland in southwest-England attempting to revive the industry. This kind of regenerative and sustainable fibre may form the basis of a transformative design-led future politics of regrowth and sustainability.

Image 5: Agricultural Workers Heckling Flax, ca. 1880. Credit: A print from Great Industries of Great Britain, Volume I

Modular garment systems - designed for repair, reuse, and recycling - can further extend product lifespans and reduce waste (Casciani 2023). Circular design principles, including localized production and ethical procurement, align with NHS Scotland's Climate Emergency and Sustainability Strategy 2022–2026, which prioritizes sustainable goods and services, travel, buildings, care, and communities (Scottish Government 2022). Integrating scrub redesign into this framework ensures that textile innovation contributes meaningfully to national climate targets. Redesigning scrubs through a sustainability lens offers a tangible opportunity to reduce emissions while improving staff experience. By shifting to biodegradable materials, enhancing garment durability, and adopting circular models, the NHS can significantly reduce the carbon footprint of its clothing systems. Such interventions also serve as visible symbols of climate leadership, reinforcing the NHS's identity as a values-driven public institution.

NHS and Procurement Ethics

The procurement of hospital scrubs within NHS Scotland exemplifies the complex interplay between global supply chains, ethical responsibility, and design-led innovation (Koskinen et al. 2012). Currently, NHS Scotland sources scrubs from multinational suppliers with manufacturing operations in Canada, Portugal, and China. While this model ensures scale and cost-efficiency, it raises concerns about transparency, labour conditions, and environmental oversight, issues that are increasingly central to public sector procurement reform (Boulding 2021).

The NHS has adopted ethical sourcing frameworks such as the Labour Standards Assurance System (LSAS), which sets minimum standards for labour rights and working conditions. However, implementation remains inconsistent, particularly in complex, multi-tiered supply chains where visibility is limited. Design research offers critical insights here: as Demircioglu and Vivona (2021) argue, procurement should be understood not only as a transactional mechanism but as a procedural tool for innovation, capable of shaping systemic outcomes through iterative, stakeholder-driven processes.

Labour rights in the global garment industry remain a pressing concern. Workers in low-wage economies often face exploitative conditions, with limited access to collective bargaining or workplace protections. Ethical procurement must therefore move beyond compliance checklists to embrace human-centred design principles that foreground dignity, equity, and wellbeing. As Holeman and Kane (2020) note, design with dignity involves empathetic engagement with users, whether patients or staff, and the creation of environments and artefacts that reflect care, autonomy, and respect.

Within the NHS, cost-cutting has led to a decline in garment quality, affecting staff comfort, safety, and morale. Uniforms are not neutral; they carry symbolic weight and shape professional identity. Design thinking, with its emphasis on user experience, iterative prototyping, and cross-disciplinary collaboration, offers a pathway to reimagine scrubs as tools of empowerment rather than constraint (Alvarez & Marsal 2022). Emerging frameworks in circular procurement advocate for designing products for reuse, repair, and recycling. Circular design principles - such as modularity, material recovery, and lifecycle thinking - can be embedded into NHS procurement to reduce waste and support local economies. The Ellen MacArthur Foundation (2023) for instance highlights how city governments and public institutions can leverage procurement to drive market demand for circular solutions, shifting from linear 'take-make-dispose' models to regenerative systems.

Design-led approaches to circular procurement also emphasize stakeholder co-creation, aligning with co-design methodologies that engage end-users in shaping solutions. Bird et al. (2021) propose a generative co-design framework for healthcare innovation, demonstrating how participatory design can translate lived experience into actionable procurement criteria. This is particularly relevant for NHS uniforms, where staff input on fit, function, and sustainability can inform procurement specifications that prioritize wellbeing and performance.

As one of the UK's largest employers and purchasers, the NHS has a moral and strategic responsibility to lead by example in ethical and sustainable procurement. The Net Zero Supplier Roadmap and Social Value Playbook embed sustainability and social justice into procurement practices, requiring suppliers to publish carbon reduction plans and demonstrate alignment with net zero goals. Design research reinforces this shift, positioning procurement as a site of innovation, inclusion, and systemic transformation.

How Can Design Help?

While design is often misunderstood as a matter of aesthetics or surface-level change. In reality, design is a powerful tool for systems thinking, participatory innovation, and cultural transformation (Milton & Rodgers 2023). In the context of NHS scrubs, design can help reimagine not only the garments themselves but the values, relationships, and infrastructures that underpin them.

- **First, design offers a user-centred approach**. By engaging healthcare workers in the co-design of scrubs, we can ensure that garments reflect the realities of clinical work - its physical demands, emotional labour, and symbolic dimensions. Co-design processes also foster ownership and dignity, allowing staff to feel seen and valued in the systems they serve.
- **Second, design enables material experimentation**. Designers can explore alternative fibres (e.g. flax, hemp, bamboo, lyocell), natural dyes, and low-impact manufacturing techniques. These innovations can reduce environmental harm while also enhancing comfort, breathability, and aesthetic appeal.
- **Third, design supports iterative prototyping and testing**. Rather than committing to a single solution, design-led projects can trial multiple approaches, gather feedback, and refine over time. This is particularly valuable in complex systems like healthcare, where change must be both evidence-based and adaptable.
- **Fourth, design can help tell new stories**. Uniforms are not just functional, they are symbolic. They communicate identity, hierarchy, and institutional values. A redesigned scrub can signal a shift toward a more sustainable, inclusive, and caring NHS. It can embody the principles of climate justice, workplace dignity, and public service innovation.

In this way, design is not a luxury or an afterthought; it is a strategic capability for transforming healthcare systems from the inside out.

Conclusions – Scrubs and Net-zero Politics

This research offers a critical intervention into the politics of sustainability within NHS Scotland, reframing hospital scrubs not as passive procurement items but as politically charged artefacts embedded in broader systems of governance, labour, and climate accountability. While healthcare decarbonization efforts have traditionally focused on infrastructure, pharmaceuticals, and energy systems, this project demonstrates that textiles (particularly scrubs) are a strategic and symbolic site for climate action, institutional reform, and cultural transformation.

Through a design-led, co-creative methodology, this work surfaces the lived realities of healthcare workers and exposes the limitations of current procurement models, which prioritize cost-efficiency over dignity, sustainability, and ethical labour practices. The co-design pop-up at Golden Jubilee Hospital revealed how garments shape not only physical comfort and clinical performance but also professional identity, morale, and institutional belonging. These insights challenge the technocratic logic of uniform standardization and call for a more democratic, inclusive, and values-driven approach to healthcare design.

The environmental politics of scrubs are equally urgent. Fossil-fuel-derived materials, energy-intensive laundering, and incineration-based disposal systems contribute significantly to NHS Scotland's Scope 3 emissions. Yet these impacts remain largely invisible within mainstream sustainability strategies. By proposing plant-based, biodegradable alternatives and circular design principles, this project foregrounds the material politics of healthcare and advocates for a transition away from extractive, linear systems toward regenerative, locally accountable models.

At the heart of this work is a critique of public procurement as a political instrument. The current model - characterized by globalized supply chains, opaque labour conditions, and short-term cost savings - undermines the NHS's stated commitments to climate justice and social value. Design research reframes procurement as a site of innovation and ethical negotiation, where stakeholder engagement, iterative prototyping, and human-centred governance can produce more equitable and sustainable outcomes. This aligns with emerging frameworks in circular procurement and public sector design, which position institutions not merely as service providers but as stewards of social and environmental futures.

Moreover, this project contributes to a growing body of scholarship that views design as a form of political agency. By engaging healthcare workers in the redesign of their uniforms, it challenges hierarchical decision-making structures and redistributes power within the organization. It also highlights the risks of superficial co-design, cautioning against tokenistic participation and advocating for deeper, more accountable forms of collaboration. In doing so, it opens up space for imagining alternative futures; where garments are not only functional but also expressive of institutional values such as care, equity, and sustainability.

Ultimately, this work demonstrates that design is not a peripheral concern but a core capability in the political project of net-zero healthcare. It shows that even the most routine elements of clinical infrastructure - when reimagined through participatory and sustainable design - can catalyze systemic change. As NHS Scotland positions itself as a global leader in climate-conscious healthcare, the redesign of scrubs offers a visible, scalable, and politically resonant intervention. It invites policymakers, designers, and healthcare leaders to consider how everyday artefacts can become tools for reconfiguring systems, advancing justice, and building a more resilient and inclusive public health future.

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From Rust Belt to Renewal: Bionic Design Empowering Resilient Urban Construction in China — Exploring a Synergistic Transformation Pathway for Production, Ecology, and Culture in Resource-based Cities

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Abstract

This study examines Pingdingshan City in Henan Province, China's first large-scale coal mine base independently explored and designed, as a typical case to break through the limitations of the traditional deindustrialization model. Based on the bionic structure-function-metabolism integrated concept, it innovatively constructs a production-ecology-culture tripartite symbiotic paradigm. This paradigm reconstructs the ecological network of industrial sites through structural bionic technology, achieves the cascade utilization of industrial resources and ecological cycles through functional bionic means, and extracts industrial heritage symbols through cultural bionic methods to build a city's cultural gene bank, thereby promoting the transformation of resource-based cities into resilient cities. In terms of practical effectiveness, by the end of 2024, Pingdingshan's nylon industrial cluster had successfully implemented 71 key projects, significantly promoting regional economic development. Meanwhile, through ecological restoration and cultural reshaping measures, the biodiversity in the region has shown a significant recovery trend, industrial cultural identity has been greatly enhanced, and community cohesion has also been significantly strengthened. At the theoretical level, this study introduces bionic principles into the field of urban design for the first time, deeply revealing the synergistic mechanism of the three elements of production-ecology-culture. At the methodological level, it constructs a triple dimension regenerative design model, providing a scientific tool for quantitative evaluation of urban transformation benefits. At the practical level, it provides replicable and scalable transformation paths for cities along the Belt and Road Initiative, which is highly consistent with the goals of the United Nations New Urban Agenda, contributing Chinese wisdom and Chinese solutions to the sustainable development of resource-based cities worldwide.

Keywords: Bionics, Pingdingshan City case, resilient city, resource-based city transformation, tripartite symbiotic paradigm.

Introduction

Resource-depleted cities worldwide face economic recession, ecological degradation, and population decline. China, with 69 such cities, has the largest number globally, and its transformation challenges are particularly representative. Facing complex global transformation challenges, the traditional deindustrialization-centric single economic development model reveals issues such as low efficiency in ecological restoration, exacerbated cultural discontinuity, and insufficient social resilience. For instance, ecological restoration often focuses solely on vegetation coverage while neglecting functional recovery of ecosystems; industrial heritage disposal is crude, leading to cultural fragmentation; and lack of public participation weakens social resilience during transformation. Taking Pingdingshan City in Henan Province — China's first large-scale coal mine base independently explored and designed — as a case, this study proposes transcending traditional frameworks by applying bionic principles to construct a production-ecology-culture tripartite symbiotic paradigm, driving resource-based cities toward resilient urban transformation.

1. Research Status of Resource-based City Transformation in China

Since the founding of the People's Republic of China, domestic scholars have conducted continuous exploration on the transformation of resource-based cities, with their research trajectories closely intertwined with the national industrialization process and urban development policies. Based on the evolutionary characteristics of research themes and methodologies, relevant studies can be categorized into three distinct stages:

a) Planned Economy-Driven Urban Geographical Research (1949-1978)
This phase was profoundly influenced by the national strategy of priority development of heavy industry. In the early years of the People's Republic of China, resource shortages compelled large-scale mineral exploration, and the construction of energy bases led to the concentrated emergence of resource-based cities such as coal and oil hubs. Academic research centred on urban geography, focusing on population migration patterns driven by resource development (e.g. the family-style mobility model where mine workers' families relocated together), mechanisms of labor spatial allocation (e.g. job allocation systems under planned economy), and policy designs for resource-based cities serving national strategies (e.g. industrial layout adjustments during the Third Front Construction period). Research in this stage was characterized by strong policy orientation but limited theoretical construction, primarily relying on empirical summaries due to historical constraints.

b) The Exploration of Sustainable Development in Market-Oriented Transformation (1979-1999)
As resource extraction entered a stable production period, the development contradictions of resource-based cities gradually became prominent. Mechanical population growth led to urban scale overloading (e.g. the mining city population inflation phenomenon in Northeast China's old industrial bases), while environmental pollution caused by resource development (such as air and water pollution) emerged as critical constraints on urban development. Academic research began shifting toward an urban development perspective. Scholars systematically analyzed the life-cycle characteristics of resource-based cities and attempted to construct sustainable development frameworks through academic conferences (e.g. the First National Conference on Resource-Based Cities in 1985) and specialized studies. The achievements of this stage were primarily focused on summarizing the development patterns of resource-based cities (e.g. life cycle theory, industrial decline early warning mechanisms) and proposing policy recommendations (e.g. industrial diversification pathways). However, there was a lack of interdisciplinary methodological integration, and empirical studies were mostly based on case analyses.

c) In-Depth Comprehensive Research in the Context of Globalization and Digitalization (2000-Present)
Since the 21st century, research on resource-based cities has undergone three major shifts, including:

Scale expansion: transitioning from single-city analysis to regional synergy (e.g. studies on resource-based city clusters in the Central Plains Economic Region), focusing on inter-city industrial linkage and factor mobility.

Problem dimensional deepening: research content extends to urban risk mechanisms (e.g. social stability risks in resource-depleted cities), economic restructuring (e.g. pathways from resource dependence to innovation-driven development), ecological compensation mechanisms, and other domains.

Methodological innovation: interdisciplinary research has become mainstream (e.g. integrated analyses combining geography, economics, and sociology), with big data and quantitative models widely applied to assess urban transformation performance.

2. Paradigm Innovation in Bionic Design: A Resilient Urban Transformation Path Based on the Tripartite Symbiosis of Production-Ecology-Culture

a) Theoretical Breakthrough in Paradigm Construction: Interdisciplinary Integration of Bionics and Urban Design

Addressing the vicious cycle of production expansion — ecological degradation — cultural rupture in the transformation of resource-based cities, this study innovatively introduces the integrated concept of structure — function — metabolism from bionics into the field of urban design, constructing a tripartite symbiotic paradigm of production — ecology — culture. This paradigm breaks through the traditional single-dimensional governance model and, through the systematic integration of structural bionics, functional bionics, and cultural bionics, enhances the resilience of urban systems:

Structural resilience: optimizing the urban spatial framework and enhancing the ecological network's resistance to disturbances.

Functional resilience: building a resource circulation system to enhance the adaptive capacity of production systems.

Cultural resilience: activate the carriers of collective memory and strengthen the cohesion of social and cultural identity.

This paradigm provides a theoretical framework and practical path for the transformation of resource-based cities into resilient cities through the ecology–industry–culture co-evolution.

b) Structural Biomimicry: Spatial Reconstruction and Stability Enhancement of Ecological Networks

Drawing on the spatial organizational logic of biological communities as patch–corridor–matrix, the stability of the system is enhanced through the topological optimization of ecological elements.

Ecological patch restoration: carry out ecological transformation of abandoned mining areas and industrial sites by introducing native plant communities and microbial systems, forming multifunctional ecological patches with self-sustaining capabilities.

Green Corridor Connection: construct an ecology–ventilation–culture integrated corridor, linking urban green spaces, water systems, and industrial heritage nodes, enhancing ecosystem connectivity and species migration efficiency.

Multi-scale coordination: plan ecological security patterns at the regional level, optimize the layout of green space systems at the urban level, and restore micro-ecology at the site level, forming an ecological network supported step by step from the macro to the micro scale.

c) Functional Biomimetics: Hierarchical Recycling and Efficiency Revolution in Resource Metabolism

Simulate the material cycle mechanism of biological metabolism intake–transformation–excretion–reuse to build a closed-loop system for industrial resource utilization.

Industrial Metabolism Chain Construction: breaking down the industrial production process into three metabolic units of raw material input – product manufacturing – waste recycling, for example, using the residual heat of a steel plant for heating surrounding communities, and producing new building materials from waste slag.

Industrial Symbiosis Network: build a cross-industry metabolism platform, quantify resource flow paths through modeling, and achieve cascading use of energy, water, and solid waste (e.g. wastewater-to-irrigation cycles between chemical plants and agricultural parks).

Metabolic efficiency assessment: establish a three-dimensional evaluation system of resource utilization – waste intensity – environmental load to dynamically optimize the metabolic network structure.

d) Cultural Biomimicry: The Gene Pool Inheritance of Collective Memory and the Activation of Cultural Resilience

Extract the patterns of biological genetic information transmission and achieve the intergenerational inheritance of urban cultural genes through the encoding, storage, and decoding of cultural symbols.

Extraction of cultural symbols: Systematically compile the material symbols (such as old factories and machinery) and intangible symbols (such as model worker spirit and production skills) in industrial heritage to build an industrial culture gene bank.

Scenario-based regeneration: Embedding cultural symbols into urban spaces to create interactive platforms such as industrial museums, cultural theme parks, and memory streets, and enhancing cultural identity through immersive experiences.

Dynamic updating of the gene bank: Establish a digital archive of cultural symbols, support the new generation of residents in participating in the recreation of cultural genes, and form a dynamic cycle of protection – inheritance – innovation.

e) Paradigm Value: The Interdisciplinary Practical Significance of Resilient Urban Transformation

The proposed production-ecology-culture ternary symbiotic paradigm achieves the following breakthroughs:

Theoretical innovation: for the first time, the principles of bionics are systematically applied to the study of urban resilience, revealing the synergistic mechanisms and dynamic equilibrium laws of the ternary system.

Method integration: through three-dimensional biomimicry of structure–function–metabolism, a quantifiable design toolkit and evaluation metric system are provided.

Practice-oriented: it provides an integrated solution of ecological restoration – industrial upgrading – cultural revival for the transformation of resource-based cities, aligning with the United Nations' New Urban Agenda development goals of being inclusive, safe, resilient, and sustainable. This paradigm not only offers the academic community a model for interdisciplinary research but also guides practitioners toward a sustainable path of production – ecology – culture coordinated development, offering significant reference value for the global transformation of resource-based cities.

3. Case Verification: Pingdingshan, Henan Province – China's First Coal Mine Base Independently Explored and Designed for Transformation Practice

After the founding of New China, a large number of cities focused on resource extraction emerged, making a significant contribution to economic construction. With the depletion of resources, transformation became inevitable. This study selects Pingdingshan City in Henan Province, the first large-scale coal mining base independently explored, designed, and constructed by New China, as the research object, which is highly representative. Pingdingshan City is located in the south-central part of Henan Province and is a resource-based city with strong representational significance in China, a mining and industrial city mainly focused on the coal and electricity industry. On 26 March 1957, with the approval of the State Council, Pingdingshan City was established. The city is situated in one of the national strategic development centres, and its economic development exhibits distinct stages: experiencing the period of reform and opening-up, the stable development phase until the late 1990s, and the rapid growth period after the 1990s.

Image 1: The first pair of mines in Pingdingshan City. Credit: Pingdingshan Yearbook

Image 2: The hardships of life during the early construction period of Pingdingshan. Credit: Pingdingshan Yearbook

Due to the decreasing coal resources, the economy and industries have begun to transform, leading to a continuous decline in regional development status. Pingdingshan generally ranks in the middle within the province. In 1990, its GDP was third among the 18 cities in the province, but by 2016, its GDP ranking had fallen to only twelfth. Among the prefecture-level cities in Henan Province, the GDP gap within the third tier is small, making competition relatively fierce.

From 2011 to 2015, Pingdingshan City withstood the severe impact caused by simultaneous declines in both the quantity and price of major industrial products such as coal and steel, yet its economy still maintained an average annual growth rate of 7.1%. Efforts were made to promote the upgrading of traditional industries, strengthen their capabilities, and facilitate transformation and modernization. The utilization of resources such as coal, iron ore, and salt was deepened to further extend industrial chains, increase product added value, consolidate advantageous foundations, establish core industrial competitiveness, and shift from merely focusing on quantity to building industrial clusters. Strategic emerging industries were cultivated to achieve diversified development. The full industry chain model was implemented to promote the integration of tourism with industry, agriculture, and the service sector.

In 2016, economic development shifted from high-speed growth to medium-high-speed growth, and Henan Province's economic ranking frequently declined. The city still mainly focused on resource-based heavy industries, with coal mining dominating, making industrial transformation relatively slow. The industrial structure was traditional, consistently maintaining a two-three-one pattern, dominated by resource-based heavy industries, with coal mining still accounting for a quarter. In 2016, the structure of tertiary industries in Pingdingshan was 9.7:49.0:41.3. In the total industrial output value, heavy industry accounted for 75.3%, while light industry accounted for only 26.5%.

For the efficient use of resources and green sustainable development, the *Overall Plan for Mineral Resources in Pingdingshan City* (2016-2020) clearly states that the scale and structure of mining operations need to be adjusted and upgraded. Mineral resources should be conserved and used comprehensively, the mining circular economy should be developed, and research on the comprehensive utilization of various types of minerals should be carried out. The construction of green mines should be strengthened, along with enhanced policy guidance, support, and the adoption of the green mine development concept. The protection of the geological environment of mines should be reinforced, and based on ground subsidence and landscape destruction caused by open-pit and underground mining, key areas for geological environment management of mines should be planned.

Based on the underlying logic of ecological regeneration the bionic metabolic system is reconstructed through three-dimensional collaborative design of production, ecology, and culture. The specific pathway for Pingdingshan is as follows.

Production Transformation: Metabolic Restructuring and Recycling of Industrial Resources

Pingdingshan proactively promoted industrial transformation before the exhaustion of coal resources by cultivating emerging industries (such as new energy, new materials, and equipment manufacturing) and upgrading traditional industries (such as the refined development of coal chemical industries), successfully breaking the coal-dominated industrial structure. The transformation of the economic system not only drove the optimization of the employment structure and diversification of fiscal revenue but also created a new pattern of multi-industry coordinated development, laying a material foundation for enhancing urban resilience. For the coal-silane, coal-nylon, coal-high-purity hydrogen industrial chain, a three-level metabolic network model is proposed:

Primary metabolism: extract silane and nylon raw materials by coal combustion, achieving the conversion from traditional resources to new energy.

Secondary metabolism: convert by-products from the nylon production process (such as catalyst residues and waste polymers) and silane-synthesized silicon-containing waste into recycled raw materials through chemical recovery or pyrolysis technology.

Ultimate Metabolism: establish a three-level circulation system of Enterprise-Park-City to achieve closed-loop utilization of wastewater, reclaimed water, and miscellaneous water, significantly improving resource recycling rates.

Ecological Transformation: Ecological Renewal and Cultural Identity Reconstruction of Industrial Sites

Resource-based cities, which are dominated by the extraction and processing of natural resources, experience significant direct or indirect impacts on the urban surface due to resource extraction. The so-called urban pits have also been cleverly utilized in the development of resource-based cities. The Bailuzhou Urban Wetland Park in Pingdingshan City, Henan Province, covers an area of 1350 acres and is a city wetland recreational park transformed from the waterlogged abandoned land of the collapse area of the city's Qimu coal mine. It is now a popular spot for local residents to walk and exercise. The northern part of the wetland park is a collapsed coal mining area, and this land is gradually subsiding and waterlogging due to related effects. In 2005, the local government turned the naturally waterlogged area into an artificial lake, where large amounts of cattails and reeds grew naturally, and lotus and water lilies from West Lake were introduced. The southern part is planted with numerous trees, with wild grass and shrubs thriving along the lake, creating a small ecosystem with birds, reptiles, and wild plants.

To restore the ecosystem, Pingdingshan City has implemented a trinity project of geological stabilization – ecological reconstruction – landscape enhancement. Using the grouting reinforcement and layered backfilling technique, areas with collapse depths exceeding 3 metres were consolidated, controlling surface subsidence within ±3 centimeters; a multi-layered vegetation system of trees, shrubs and herbs was established, planting locally suitable tree species (such as Chinese Scholar Tree and Chinaberry) and aquatic plants (such as reeds and calamus), forming a stable interlaced water-land zone. After restoration, the vegetation coverage in the area increased to 85%, and the number of animal species rose from 27 before restoration to over 50 (including national second-level protected animals such as the Eurasian kestrel and egret). The restored area was planned as a national urban wetland park (approved in 2021), with facilities such as bird-watching platforms and ecological trails, creating an urban ecological core area.

Image 3: National urban wetland park in the reconstructed collapse area of the seventh mine in Pingdingshan. Credit: Jingwen Yang

Cultural Transformation: The Proposal of the Concept of Cultural Wholeness

Improving the overall cultural integrity of resource-based cities has far-reaching significance for national development and can provide spiritual support for the adjustment of local development strategies. Currently, urban regional competition has shifted from a contest of economic strength to a contest of cultural soft power, and cultural integrity is the core of the soft power of resource-based cities. Enhancing cultural soft power can not only provide fundamental material for the transformation and reconstruction of national ideology but also provide intellectual support for modernization; at the same time, the continuous improvement of cultural integrity is also a process of deeply practicing the socialist core values.

By evaluating the value, preservation status, and current use of industrial structures and equipment with historical marks and contemporary characteristics, they can be classified into four categories: industrial heritage, industrial remnants, former industrial sites, and currently existing industrial structures. In this study, twelve mining areas in Pingdingshan are classified at the current stage as currently existing industrial structures, all of which are still in use and possess potential heritage value. Since mining began in Pingdingshan in the 1950s, these structures have been continuously used to the present day, accumulating unique intrinsic value.

The industrial production equipment in Pingdingshan coal mining areas are tangible witnesses to 70 years of coal mining history; making full use of this equipment is the best way to preserve the city's memory as it not only holds great historical and educational significance but also allows mine workers to develop emotional resonance, a sense of belonging, and identity recognition. Specific renovations can follow these guidelines: retain original educational and cultural buildings (such as schools); convert office buildings into art and cultural centres, senior universities, or service centres; transform production warehouses into commercial buildings, adding supermarkets, dining spaces, entertainment venues, and creative markets (new functions will drive development in the surrounding mining areas); convert medium-size silo buildings into exhibition halls or museums; transform production culture corridors into cultural exhibition spaces combining equipment displays, historical presentation, and immersive experiences; and redevelop transportation-related buildings as rail-themed scenic connection areas.

Based on the previously constructed evaluation indicators for the current value of industrial assets in Pingdingshan, all 12 mining areas were scored. Combining these scores with the actual conditions of each mining area and feedback from interviews and surveys on public needs, targeted recommendations were developed. The reuse of existing industrial structures based on public needs, as they carry collective memories of residents, can fundamentally enhance the public's recognition of the existing industrial structures in mining areas, transforming industrial culture into a spiritual force and consolidating the core values of citizens.

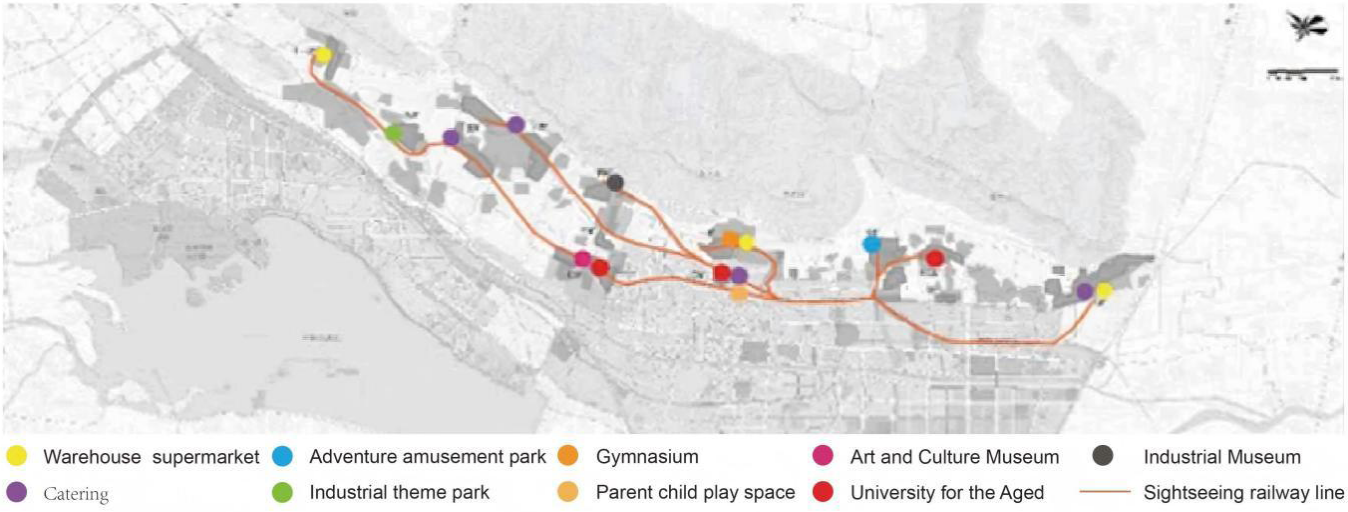

Figure 1: Diagram of the names of existing industrial renovation projects in coal mining areas of Pingdingshan City based on the survey questionnaire. Credit: Jingwen Yang

Conclusion

As China's first large-scale coal mining base designed and developed independently, Pingdingshan's transformation practice provides a vivid Chinese example for tackling the global issue of urban decline after mining depletion in resource-based cities. This study goes beyond the conventional deindustrialization mindset, converting the biomimetic integrated logic of structure–function–metabolism into a transformation pathway of production–ecology–culture coordinated action, ultimately enabling this old industrial city to make the leap from a black coal mine to a green materials capital.

From the perspective of practical effectiveness, the three-dimensional biomimetic strategy has brought concrete developmental breakthroughs: at the ecological level, structural biomimetic technology has addressed geological management challenges in mined-out and subsidence areas, freeing up ecological space for urban transformation; at the industrial level, the functional biomimetic concept has significantly promoted the upgrading of the nylon industry. Since 2019, it has been part of the national strategic emerging industry cluster, and Pingdingshan has established the national-level platform China Nylon City. The production capacity of four product categories, including Nylon 66 industrial yarn and tire cord fabric, has become the largest in the world, with 71 key projects implemented and projects such as 200 000 tons of Nylon 6 chips put into production, directly achieving a fundamental transformation of the city's industrial positioning; at the cultural level, culturally driven biomimetic approaches have revitalized industrial heritage, with 12 active mining areas becoming carriers of urban memory, enhancing community cohesion. More importantly, the synergy formed by these three aspects demonstrates that the transformation of resource-based cities does not need to occur at the expense of industrial history or the ecological environment; rather, value can be created through the integration of elements.

From a broader value perspective, the significance of this study goes far beyond a single urban case: domestically, its path of ecological restoration first, industrial upgrading as the core, and cultural revitalization to empower provides a replicable operational paradigm for similar resource-based cities across the country. In particular, the three-dimensional model of regenerative design based on quantitative data from Pingdingshan, has established a scientific evaluation standard for transformation, making the abstract concept of resilience building measurable and actionable. On a global scale, this practice aligns closely with the United Nations' Sustainable Development Goals outlined in the New Urban Agenda. The industrial upgrading model of the China Nylon City and its experience in the living preservation of industrial heritage offer concrete references for resource-based cities along the Belt and Road as well as elsewhere to transform from a rust belt to new vitality, further enriching the theoretical and practical system of sustainable urban development worldwide.

In the future, as the concept of biomimetic design is further deepened in the field of urban transformation, the resilience building of resource-based cities may see more innovative possibilities. The practice in Pingdingshan teaches us that only by respecting the laws of urban development and integrating the logic of natural ecology with the inheritance of industrial culture can we truly achieve the sustainable renewal of resource-based cities, contributing more Chinese wisdom to the transformation of old industrial bases worldwide.

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Growing Futures: A Mycelium, Robotics, Human Ecosystem

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Abstract

The depletion of natural resources and the urgent need for sustainable alternatives have accelerated the exploration of biofabrication and nature-based design solutions. Within this framework, mycelium-based materials have emerged as a promising avenue due to their regenerative potential, adaptability, and capacity to transform waste into value. Recent advancements in robotics and material science further enhance their applicability, opening possibilities for bio-integrated systems that unite living organisms and autonomous technologies. This paper presents the Growing Futures Process, a mycelium, robot, human ecosystem that envisions biodegradable and adaptable habitats co-created through collaboration between mycelium, robot swarms, and humans. The project transforms local food waste into regenerative structures, proposing a new design and production model rooted in circularity and ecological intelligence. It outlines the key research, experimentation, and prototyping phases that informed the development of the concept.

Developed within the framework of the MUSAE project (S+T+Art programme) coordinated by Politecnico di Milano, the Growing Futures Process was conceived through a speculative future scenario following the Design Futures Art-driven (DFA) methodology. The concept evolved through four main phases: challenge exploration, inspirational research, idea generation, and concept development. The prototype-building phase involved twelve iterative experiments testing mycelium growth, sensor integration, and robotic interaction to optimize biofabrication within an ecosystemic context. Four experimental settings were explored: unconstrained growth, controlled casting, robots as nutrient dispensers, and full ecosystem integration. By integrating biological intelligence, robotics, and material science, Growing Futures proposes a novel paradigm for design – one that merges new production methods and environmental restoration into a unified, regenerative process of co-creation with nature. In doing so, the project advocates a shift from designing with nature to co-designing with nature, where humans, mycelium, and robots collaborate to shape regenerative systems.

Keywords: Biofabrication, biodesign, biomimicry, growing materials, regenerative design, speculative design.

Image 1: Growing Futures. Credit: Daniela Amandolese and Basque BioDesign Center

1. Introduction: From Extraction to Growth

The relentless exploitation of resources, coupled with increasing demographic pressure, has led to an unsustainable model of production and consumption. As Genovesi and Pellizzari (2021) remind us, matter is finite. Yet, many contemporary production models continue to operate as if it were infinite.

The urgency to move beyond sustainability, often focused on damage control, toward regenerative approaches that restore, replenish, and revitalize is undeniable. Regenerative design challenges the industrial-age paradigm of the world as a machine and instead embraces a biocentric worldview where the world is seen as a living organism. Designers must reduce harm and become stewards of transformation and a facilitator of living processes.

The Growing Futures project merges two worlds – biological and technological – into a collaborative ecosystem. Here, mycelium, robots, and humans co-create biodegradable structures from local waste, directly on-site. Rather than imposing design on materials, the project proposes a process of bio-co-design, where the behaviour of living organisms informs the evolution of form and function.

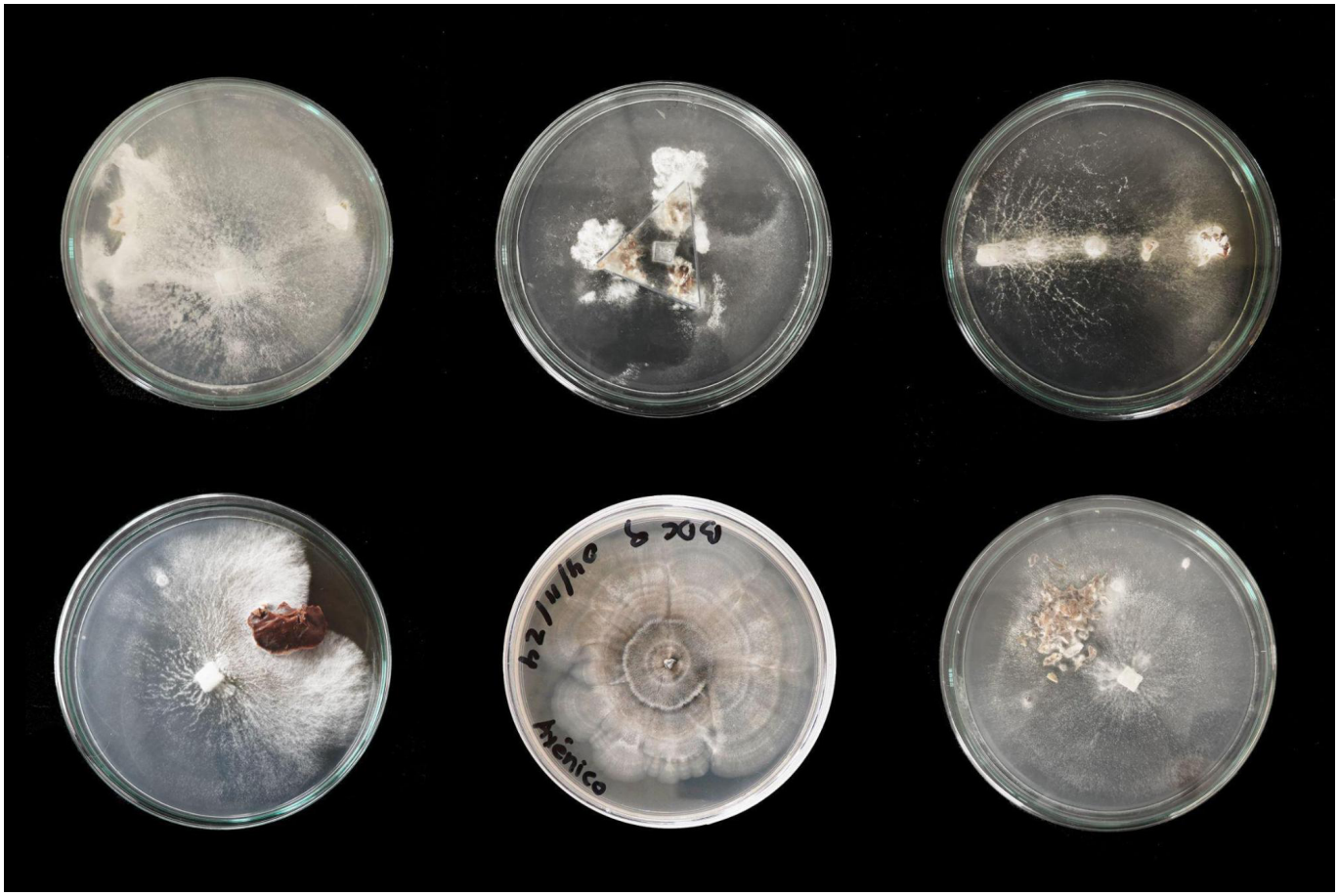


Image 2: Species of mycelium and nutrients. Credit: Daniela Amandolese and Basque BioDesign Center

This approach opens a broader reflection on the future of design: what if our role is no longer to produce artifacts but to cultivate systems capable of growing with and within the environment? In this context, the project positioned itself not merely as a design investigation, but as a speculative exploration: How can we collaborate with nature, and what does it mean to move from shaping matter to co-growing it?

2. The Mycelium: A Living Material

Mycelium – the vegetative part of fungi – plays a central role in this transition. It transforms waste into material while forming lightweight, bio-based and biodegradable structures. Its biological intelligence, expressed through decentralized growth and environmental responsiveness, offers a radical alternative to conventional materials and methods.

As a material, mycelium grows by metabolizing organic waste, binding particles into dense networks that can become lightweight, insulating, and fully biodegradable composites. These characteristics make it an ideal candidate for the construction, fashion, and packaging industries. While mycelium is becoming increasingly commonly used in design, it's often processed with traditional methods.

Growing Futures introduces a mobile, collaborative approach where fungi, robots, and humans grow structures directly on-site: an in-situ biofabrication process. Mycelium grows using local food waste as its substrate. This approach not only minimizes environmental impact but embeds design within the specific conditions of each ecosystem, promoting bioregional adaptation and reducing dependency on external supply chains.

The project uses local food waste as substrate, embodying principles of bioregional design and circular economy. Each site's ecological conditions define the behaviour of the organism, ensuring that the material outcome is context-specific rather than standardized.

3. Mycelium, Robots, and Humans: A Bio-co Design Process

The core innovation of Growing Futures lies in the creation of a feedback-based design process among three agents: mycelium, robots and humans. The project introduces a collaborative methodology in which biological, technological, and human intelligences act as co-creators within a shared ecosystem.

The process unfolds through a closed feedback loop: robots equipped with sensors monitor environmental conditions (temperature, humidity, oxygen), dispense nutrients, and regulate growth parameters. Through cloud-based dashboards, data is continuously analyzed and used to regulate growth conditions. Mycelium responds to these micro-adjustments, while humans guide the overall vision and adjust based on the input generated by the system. Inspired by the symbiotic behaviour of leafcutter ants, the robotic component began with a single unit and aims to evolve into cooperative swarms. The robots act as caregivers rather than machines of control. Their function is to support biological growth, not dominate it. Through this relationship, technology becomes part of a living ecosystem, embodying an ethics of coexistence. The design emerges through real-time negotiation rather than pre-definition.

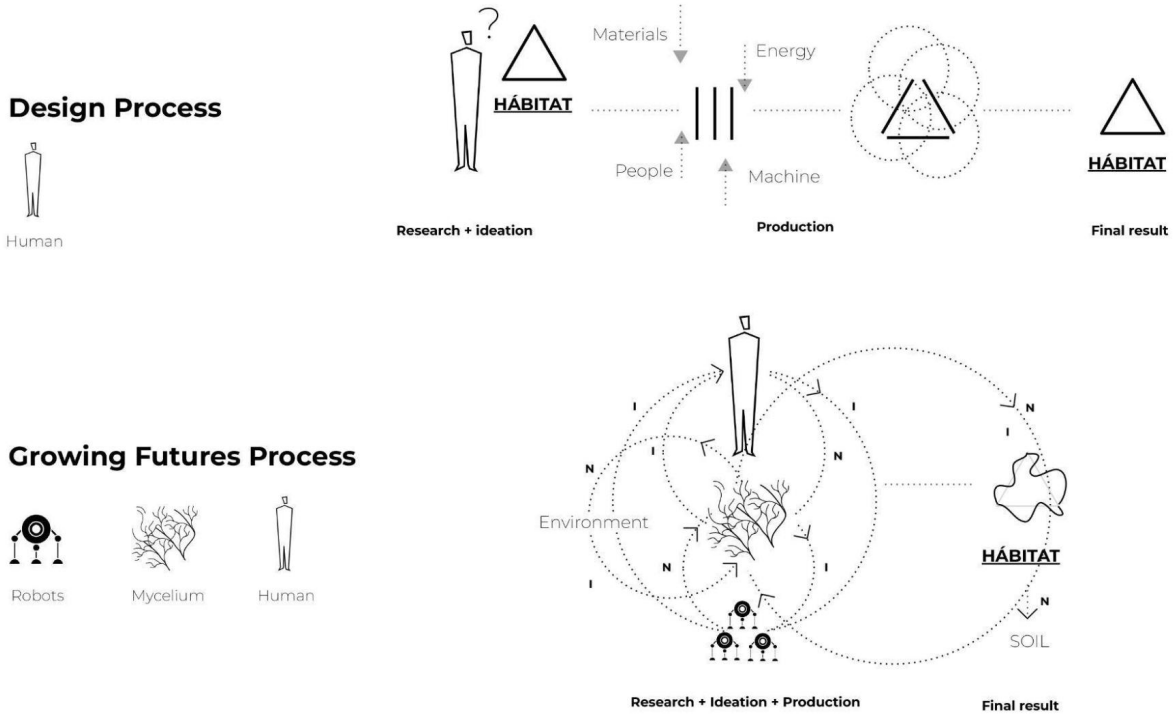


Figure 1: A comparison between the classical design process and the GFs process. Credit: Daniela Amandolese and Basque BioDesign Center

Such an approach aligns with Donna Haraway's (2016) call to "make kin, not categories", building mutualistic alliances across species and technological boundaries. It transforms the act of designing into an ecological dialogue, where materials, organisms, and systems co-shape one another.

4. Design Futures Art-driven Methodology

Growing Futures was developed using the Design Futures Art-driven (DFA) methodology (O'Gorman et al. 2025). This method played a central role in this process. Developed within MUSAE, the methodology integrates Design Futures with Art Thinking to provide structured tools for envisioning future scenarios and developing experimental prototypes. It fosters critical reflection on the cultural implications of technological innovation while grounding experimentation in real-world contexts.

The process unfolded through two macro phases: ideation and prototyping. Each phase was iterative, involving experimentation, reflection, and adaptation. The ideation phase focused on conceptual and ethical framing, while the prototyping phase translated these insights into tangible experiments with living matter and machines.

4.1. Ideation Phase

The ideation phase set the foundation for Growing Futures (GF), guiding the project from values and concepts to practical exploration. It included five stages: defining the concept and regenerative design principles; challenge exploration to identify hopes, fears, and core values; inspirational research into living materials, technologies, and artistic practices; idea exploration through expert workshops and scenario building; and concept development, which consolidated these insights into a co-creative model where humans, robots, and mycelium collaborate.

4.1.1. Concept

Growing Futures is conceived as a regenerative design process, the *Growing Futures* Process, for creating sustainable habitats at multiple scales using mycelium-based materials. The project fosters collaboration between mycelium, robots and humans, challenging the industrial-era paradigm of the world as a machine.

By leveraging natural intelligence and behavioural patterns, the process establishes a biologically driven design model. Habitats created with locally sourced mycelium are biodegradable, adaptive, and capable of returning nutrients to the soil. This regenerative cycle fosters symbiosis among humans, nature, and technology, promoting a design ethos aligned with ecological principles.

The process follows a circular, spiral model: local organic waste is transformed into adaptable structures guided by biological intelligence. Growing Futures envisions a future where production systems are organic, regenerative, and waste-free, turning by-products into resources for new growth.

4.1.2. Challenge Exploration

The first ideation phase defined the project's core values, hopes, and fears. Using the Future Compass tool, the team explored speculative scenarios. Four core values emerged:

Collaboration: fostering cross-disciplinary and interspecies partnerships.

Efficiency: minimizing waste while maximizing ecological impact.

Adaptability: designing for dynamic environmental conditions.

Responsibility: making ethical decisions for environmental and social well-being.

Hopes included transforming local waste into valuable resources, creating sustainable structures, and fostering a stronger connection between humans, ecosystems, and communities. Fears addressed safe integration of robotics with living systems, maintaining quality in experimental processes, and the long-term commitment required for regenerative production.

Fieldwork in the Basque Country involved collecting over 55 native fungal species, which were isolated and cultivated to identify the most suitable strains. Industrial food waste, particularly bagasse from beer breweries, was selected as a substrate, establishing a context-specific regenerative approach.

4.1.3. Inspirational Research

The inspirational research phase broadened the project's conceptual and practical horizons. Using platforms like Miro, research was clustered into:

Living materials: exploring mycelium's structural, ecological, and aesthetic properties, and its potential for co-creation with robots and humans.

Emerging technologies: investigating robotic systems, sensors, and biofabrication techniques to integrate with mycelium growth.

Art and design: analyzing projects across architecture, product design, and artistic practices to extract inspiration and strategies.

Complementary research included literature reviews, case studies, and AI-generated visual inspirations. This integrative approach highlighted intersections between biology, technology, and speculative design, laying the groundwork for prototyping.

4.1.4. Idea Exploration

An online Idea Exploration Workshop refined the project's direction. Experts from bio-based materials, architecture, robotics and art participated in two main activities:

1. **Scenario building:** exploring future scenarios where mycelium-based materials and autonomous systems could co-evolve, challenging assumptions and envisioning radical possibilities.

2. **Expert roundtable discussions:** evaluate feasibility, address ethical questions, and identify opportunities.

Discussions emphasized biological safety, fungal communication networks, ethical implications of robotics, and the role of art in illustrating the co-evolution of humans, robots, and fungi. This reinforced the project's speculative nature and underscored that the research process itself is as important as tangible outcomes.

4.1.5. Concept Development

The final concept, Growing Futures (GF), introduces the Growing Futures Process – a regenerative design and production approach inspired by the interconnectedness of natural ecosystems. Rooted in the dynamics of mycelium growth, environmental responsiveness, and the collaboration between humans, robots, and living matter, the process proposes a shift from designing with nature to co-designing with nature. This transition redefines the designer's role: rather than shaping matter into predefined forms, the designer becomes a facilitator of biological and technological interactions.

In traditional design, humans begin with an idea or a functional need and employ materials, energy, and tools to realize a controlled outcome. The GF Process preserves the human vision but transforms the creative act into a collaborative system of three agents: humans, robots, and mycelium. The human defines what to grow and where, through an adaptive digital interface that visualizes possible configurations according to local environmental conditions and the available type of mycelium. Robots then act as mediators, translating human input into biological action: they transport nutrients, regulate humidity and temperature, and collect real-time data on the organism's response. Mycelium, as the third actor, grows autonomously within this framework, interpreting environmental cues and interacting with robotic stimuli.

The resulting form is not imposed but *emerges* through interaction. It mirrors the initial design intent while remaining deeply rooted in its ecological and material context. The process thereby challenges the notion of authorship, introducing a triadic collaboration where creation is distributed among human, biological, and technological intelligence. The outcome is not merely a product, but a *living artifact* that continues to evolve, eventually decomposing and re-entering the natural cycle - where what is waste for one becomes a resource for another.

In this model, robots become digital caretakers that nurture biological growth rather than support it. They act as translators between organic and artificial systems, capable of learning from natural feedback loops. The collaboration between living organisms and machines thus becomes a metaphor for a new form of design ecology – one in which growth replaces fabrication, care replaces extraction, and decay becomes an essential phase of renewal.

The Growing Futures Process proposes a fundamental paradigm shift: from linear production to regenerative co-creation. It frames design as an evolving dialogue between species, technologies, and environments, suggesting that the future of production may no longer lie in constructing objects, but in cultivating ecosystems.

4.2. Prototyping Phase

The prototyping phase aimed to translate theoretical insights into practice through a sequence of twelve iterative experiments that combined biological growth, sensor integration, and robotic control. Each iteration aimed to refine the interplay between mycelium and robotics, progressively enhancing the system's precision, responsiveness, and adaptability.

1. **Unconstrained growth**: mycelium was allowed to grow freely in open conditions to observe its natural, unmediated structural behaviour. This phase served as a baseline for understanding the organism's intrinsic patterns and growth rate in relation to environmental fluctuations.

2. **Controlled casting**: growth was guided within modular moulds made from biodegradable PLA and 3D-printed structures, enabling form definition and reproducibility testing. The molds were sterilized before inoculation to ensure biological integrity.

3. **Robots as nutrient dispensers:** robotic unit was programmed to deliver water and nutrient solutions at defined intervals, simulating an automated care system. The robot also performed micro-movements around the substrate to prevent stagnation zones and improve aeration.

4. **Ecosystem integration**: this final setting established full feedback loops among sensors, environment, and robotic components, allowing adaptive responses to real-time data.

Environmental conditions were continuously monitored using a distributed network of sensors connected to Arduino Nano 33 IoT microcontrollers. The system incorporated a DHT11 sensor for temperature and humidity, a DFROBOT SEN0322 I2C sensor for oxygen concentration, and photoresistors (LDRs) to assess light intensity. All data was transmitted via Wi-Fi (ESP32 module) to a cloud-based dashboard (Blynk platform), where environmental parameters could be tracked and remotely adjusted.

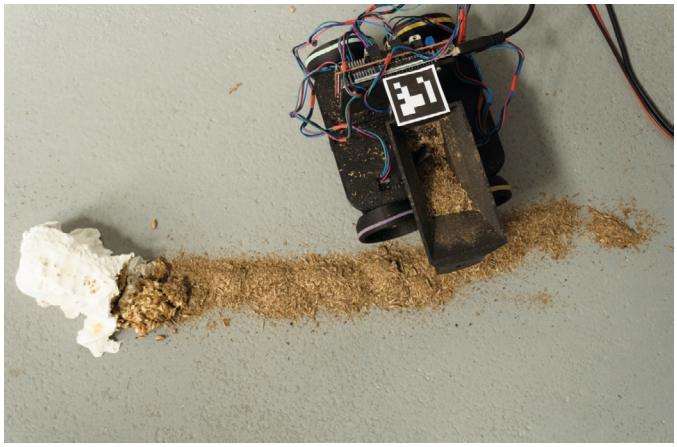
The biological component consisted of mycelium produced by one strain of *Ganoderma lucidum* and one of *Pleurotus ostreatus*, cultivated on a sterilized substrate of agricultural waste (rice husks, coffee grounds, and straw). The ratio of carbon to nitrogen (C/N) was maintained at approximately 25:1, with humidity levels between 60% and 70% and temperature controlled between 24°C and 27°C to optimize colonization speed.

The robotic prototype, initially a single manually controlled platform, was built using a Raspberry Pi 4 board, equipped with servo motors, a stepper motor driver, and an ultrasonic distance sensor (HC-SR04) for positional awareness. The prototype's software architecture was developed in Python, enabling synchronization between sensor readings and actuation logic. In later stages, the team began testing autonomous control scripts for future multi-agent applications, inspired by leafcutter ants — a biological model of cooperative behaviour where each agent performs specialized roles to maintain collective balance.

This analogy underpinned the transition toward robotic swarm design, which will be explored through open-source simulation platforms such as SMART-mBot. Here, multiple robots could coordinate nutrient delivery, environmental monitoring, and even reconfiguration of the growing structure, embodying the project's biocentric principle: technology supports and learns from biological systems rather than dominating them.

Throughout the experiments, constant calibration was required, as mycelium demonstrated high sensitivity to micro-environmental variations. Even slight deviations in temperature or moisture altered growth density and mechanical performance. The robotic and sensor systems thus functioned as dynamic mediators, adjusting conditions in response to biological feedback.

Over time, the system evolved toward autonomous, multi-agent collaboration, where swarms could collectively decide how to distribute water or reposition nutrients, embodying emergent intelligence. The relationship between growth and decay became central: structures were designed to decompose gracefully, contributing back to the ecosystem once their life-cycle ended.



Images 3 and 4: Laboratory trials: the robot distributes substrate for mycelium growth. Credit: Daniela Amandolese and Basque BioDesign Center

Image 5: A mycelium structure. Credit: Daniela Amandolese and Basque BioDesign Center

5. Applications and Cultural Shift

The potential applications of Growing Futures extend beyond experimental design into architecture, infrastructure, and environmental remediation that return to the soil after use. In remote or resource-scarce areas, such systems could offer new construction models that rely entirely on local materials and decentralized fabrication. The designer's task becomes not to shape finished products, but the facilitator of living processes.

What makes Growing Futures significant is that it reframes regenerative design not simply as a technical solution, but as a cultural shift. It invites designers to let go of control, to embrace the unpredictable, and to co-exist with the non-human world. It asks: what does it mean to co-design with nature? How can we move from manipulating matter to cultivating it?

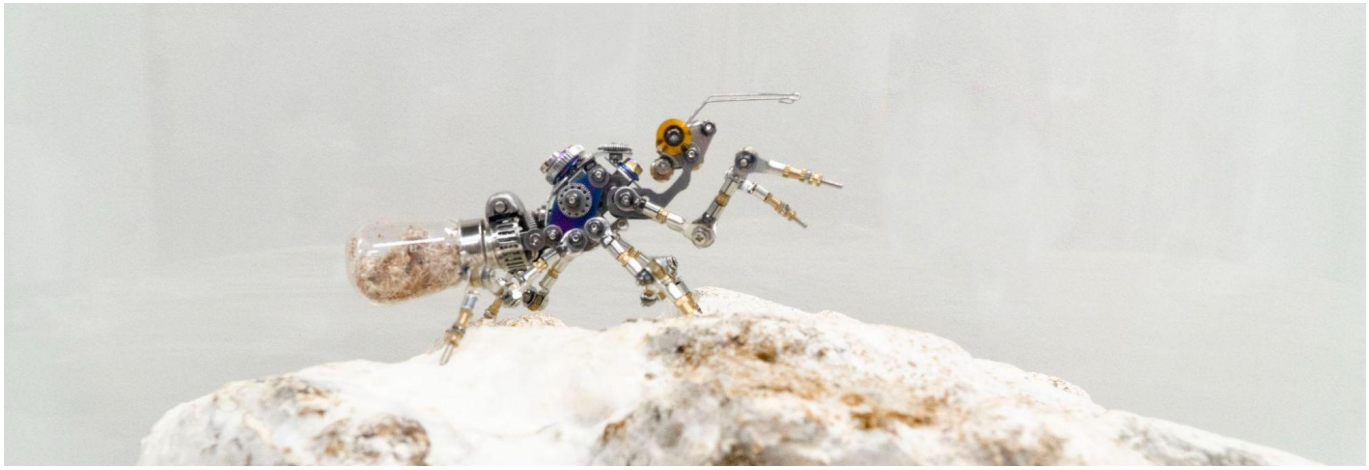


Image 6: Visualization of a speculative future scenario. Credit: Daniela Amandolese and Basque BioDesign Center

This shift is already influencing contemporary discourse. Scholars like Myers and Antonelli (2012), Karana et al. (2015), and Rognoli et al. (2015) have emphasized the emergence of material-driven and living design approaches. Projects like *Growing Futures* put these ideas into practice, creating not only new products but new relationships –– between humans, technologies, and ecological systems.

6. Conclusion

As the climate crisis deepens and the failures of extractive paradigms become unavoidable, design must rise to meet the challenge — not just by reducing impact, but by healing ecosystems, restoring materials, and reconnecting disciplines. The *Growing Futures* project offers a compelling prototype for this transformation: a design process that is regenerative, collaborative, and alive.

By integrating mycelium, robotics, and human creativity within a co-creative ecosystem, the project demonstrates how design can actively contribute to ecological renewal rather than merely mitigating environmental damage. The Growing Futures Process exemplifies a framework in which humans, fungi, and robotic agents operate in symbiosis, creating structures that are not only functional and adaptable but also biodegradable and capable of returning nutrients to the soil. This approach challenges conventional industrial production, which prioritizes permanence and extractive practices, and instead introduces a temporality rooted in cycles of growth, use, and decomposition.

The project contributes to both theoretical and practical discourses in design research. Theoretically, it expands the notion of material agency, situating mycelium as a living collaborator rather than a passive resource. It demonstrates how speculative design and systems thinking can intersect with biofabrication to envision future habitats that are responsive, adaptive, and integrated into local ecosystems. Practically, Growing Futures provides insights into the application of robotics for environmental monitoring and intervention, showing that technological tools can complement, rather than dominate, biological processes. By testing iterative prototypes under varying experimental conditions, the project underscores the significance of understanding environmental variables, such as humidity, temperature, and substrate composition, in shaping material growth and behaviour.

Furthermore, Growing Futures opens avenues for a broader reconsideration of waste and resource management. By transforming local food waste into regenerative structures, the project reframes what is typically considered refuse into a valuable input for material production, advancing circular economy principles. The integration of robotic systems, sensors, and living materials offers a blueprint for urban and architectural applications, ranging from biodegradable packaging and temporary shelters to insulation panels and adaptive urban furniture. Such applications could radically transform our approach to urban planning and infrastructure, where cities might one day "grow" organically, supported by technology in a nurturing role rather than a controlling one.

Importantly, the project underscores the ethical and philosophical dimensions of co-creation with living systems. The collaboration among humans, fungi, and robots requires careful consideration of interspecies relationships, ecological impact, and technological responsibility. Growing Futures exemplifies a design ethos that is humble, patient, and responsive, privileging dialogue over domination, observation over imposition. This perspective fosters a new understanding of design as stewardship, emphasizing care for ecological cycles, local environments, and future generations.

Looking forward, the Growing Futures process offers multiple paths for further research and application. Scaling the prototypes to larger architectural or infrastructural interventions could reveal new challenges and opportunities in material performance, ecological integration, and robotic coordination. Cross-cultural applications could explore local fungal species and organic waste streams, adapting the process to diverse environmental contexts while maintaining the regenerative principles at its core. Moreover, the project encourages reflection on the evolving role of designers as facilitators of living systems, capable of mediating between technological innovation, ecological stewardship, and cultural narratives.

Ultimately, Growing Futures envisions a world in which design is no longer an act of extraction but of cultivation. In this vision, human-built environments are dynamic, responsive, and alive; structures grow, adapt, and decompose as naturally as any organism.

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Research on Ecological Co-construction Design Practice in China's Ultra-high Voltage Transmission Corridors

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Abstract

Since 2006, China has developed the world's only nationwide Ultra-High Voltage (UHV) transmission network, a key component of the "West-to-East Power Transmission" strategy. These corridors traverse ecologically fragile regions, posing significant environmental challenges such as habitat fragmentation, soil erosion, and landscape disruption. This study proposes 'ecological co-construction' as a design-led methodology to integrate infrastructure, ecology, and society, reframing UHV corridors as sites of ecological negotiation. Focusing on case studies in western China — particularly the Qinghai-Tibet Plateau — it examines the full life cycle of UHV projects to identify ecological risks and scalable design strategies, including terrain-adaptive foundations, biodiversity-sensitive siting, and modular landscape integration. The research develops a design toolkit featuring industrial–landscape fusion, renewable energy–ecology synergy, and soil remediation with shared landscape use. Emphasizing participatory design, it integrates local knowledge and cultural practices to produce context-sensitive solutions. This framework offers a replicable paradigm for aligning large-scale infrastructure with sustainability goals, transforming infrastructure into platforms for ecological regeneration, spatial resilience, and socio-cultural renewal.

Keywords: Ecological co-construction, fragile ecosystem, infrastructure, landscape integration, sustainability.

1. Research Background and Current Situation

1.1. Research Background

Since the construction of the first AC test line was initiated in 2006, China's UHV transmission project has formed a nationwide UHV transmission network through nearly two decades of continuous exploration and practice. This achievement not only marks a major breakthrough in China's energy infrastructure construction, but also provides an important Chinese solution for the development of the world's energy Internet.

The core role of the UHV transmission corridor is to support the 'west-to-east power transmission' and optimize the allocation of energy resources in the national spatial pattern. At the same time, as one of the key technology outputs of the Belt and Road Initiative, UHV technology promotes cross-regional energy interconnection and has far-reaching significance for building a global energy Internet and promoting international energy cooperation.

However, the construction and operation and maintenance of UHV transmission projects inevitably have an impact on the ecological environment. The transmission corridors in the western region span diverse landforms such as plateaus, mountains, river valleys and grasslands. During the implementation of the projects, ecological problems such as the fragmentation of animal and plant habitats, soil erosion and the destruction of cultural landscapes have been triggered. Among them, ecologically fragile areas such as the Qinghai-Tibet Plateau are particularly prominent, where environmental sensitivity and the difficulty of restoration make the contradiction between transmission projects and ecological protection more complicated.

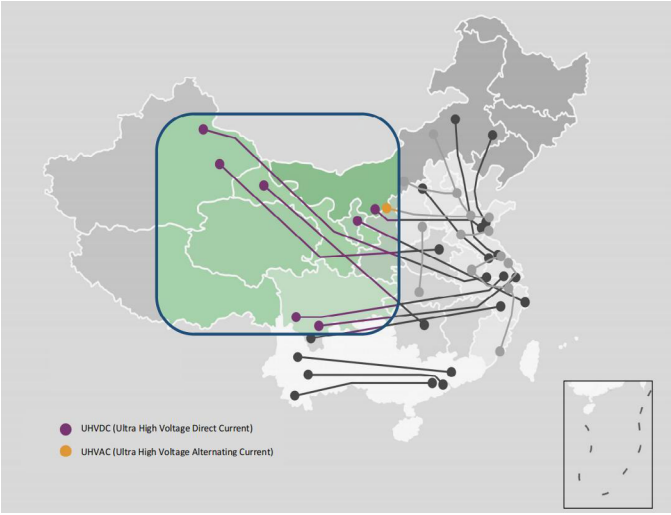

Figure 1: UHV transmission corridor network in Western China.

1.2. Research Trends

Scholars suggest that China's ecological civilization construction is of great significance to biodiversity conservation by systematically optimizing the territorial spatial pattern and strengthening ecosystem restoration and protection (Du Xiangyu 2020; Wang Mengmeng 2024; Yu Kongjian 2025). Second, at the methodological level of China's green infrastructure, scholars suggest that high-voltage corridors should be incorporated into territorial space ecological restoration planning, and through rational layout and functional design, ecological restoration strategies should be implemented to reduce their disturbance to the ecological environment (Han Zhoulin 2021; Li Hui 2022; Wang Daiyin 2022). Third, design intervenes at the methodological level of green infrastructure. Scholars propose to create regional characteristic ecological landscapes by integrating design with infrastructure projects to promote disciplinary progress and expand typological boundaries (Yu Tao 2023; Qin Wen 2023; Zhou Dezhen 2024). Internationally, research focuses include:

1. **Research on the relationship between infrastructure construction and the ecological environment**: scholars believe that infrastructure has irreversible effects on animals, plants and human creation, and advocate that infrastructure projects must reserve ecological interfaces to reduce electric fields generated by high-voltage transmission lines and high pollution from infrastructure construction (Sabine Fink 2018; Ahlbom, Tarko 2021).

2. **Measures of design intervention in infrastructure**: scholars propose ecological design strategies, emphasizing that ecological corridor design and ecological park design can effectively reduce the impact of infrastructure projects on animals, plants and human survival (Skarin 2015; Chiara Eva Catalano 2021; PN Afzelia 2022).

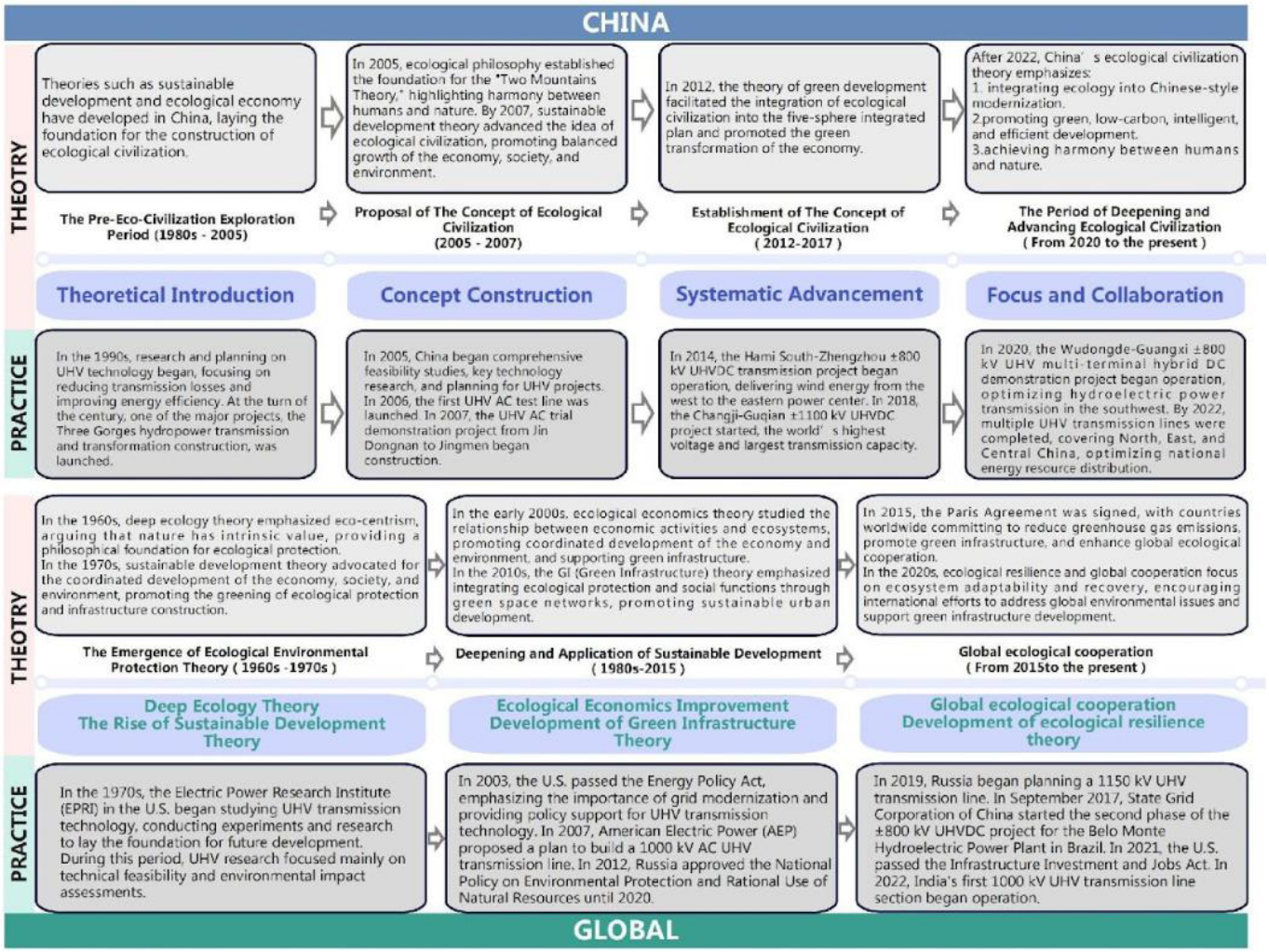

Figure 2: Research trends domestically and abroad.

Research Review:

1. Existing theoretical research focuses on the environmental impact assessment mechanism of infrastructure projects, ecological policies, environmental management during construction and operation, etc. However, there is insufficient research on establishing strategies from the perspective of design studies. Design plays a leading and bridging role, proposing innovative theories from the perspective of design studies will play a leading role in subsequent construction.
2. The existing practical research focuses on the study of specific cases, and the proposed methods such as space sharing design, engineering aesthetic design, and ecological design are scattered in various writings, lacking a systematic organization of design strategies. A systematic review from the perspective of design studies will serve as a demonstration for subsequent large-scale infrastructure projects.

2. Ecological Co-construction Design Cases for Qinghai–Tibet UHV

2.1. Background and Ecological Environment Characteristics

2.1.1. Background

The Qinghai-Tibet Plateau UHV Transmission Project is an important part of the country's 'West-to-East Power Transmission' strategy, aiming to achieve efficient transmission of clean energy and optimize the country's energy structure. The overall planning of the project takes Qinghai and central Tibet as the core of energy supply and transmits clean electricity to the eastern load centres through UHV transmission lines to form a wide cross-regional transmission network. The line runs through the hinterland of the plateau, passing through various landform zones including high mountains and valleys, grassland terraces and ice margins. It is one of the highest-altitude and ecologically sensitive transmission projects in the world, with a grand construction scale and complex geological conditions.

The construction of this project is not only a carrier for the implementation of the energy strategy, but also an important practice at the national level to explore the ecological construction model of large-scale infrastructure in plateau areas. The peculiarity lies in how to achieve the harmonious co-existence of engineering construction and ecological protection in the high-cold and fragile ecosystem while meeting the national energy security and green transition, which becomes the core challenge of design and implementation.

2.1.2. Ecological and Environmental Characteristics

The Qinghai-Tibet Plateau has unique and complex ecosystem characteristics. The main ecological types include alpine steppes, alpine shrublands, wetlands and marginal ice zones, and the structural stability and functional integrity of the ecosystem are highly dependent on climatic conditions and surface hydrological processes. The plateau region has a harsh climate, characterized by low temperatures, hypoxia, strong ultraviolet radiation, severe wind erosion, limited carrying capacity of the natural environment, and a long ecological recovery period.

The vulnerability of the plateau ecosystem is mainly reflected in three aspects. First, the composition of the biological community is single and highly sensitive to external disturbances. Second, the surface vegetation coverage is low, and it recovers slowly after being disturbed by construction or transportation. Third, permafrost is widely distributed, and once damaged, it will cause a decline in surface stability, disruption of hydrological processes and secondary disasters. Therefore, the ecological characteristics of the Qinghai-Tibet Plateau pose extremely high demands on the design of UHV projects, and a dynamic balance of 'engineering construction - ecological protection - social development' must be achieved through scientific ecological co-construction strategies.

2.2. Life-Cycle Ecological Design of UHV Projects

The ecological co-construction design of the UHV project on the Qinghai-Tibet Plateau should run through the entire life cycle of the project, covering aspects such as material selection, transportation organization, construction assembly, operation management and maintenance restoration. The design strategies at each stage together form a systematic framework for the construction of ecological symbiotic infrastructure.

2.2.1. Design of Engineering Construction Materials

Selection of environmentally friendly materials
In the complex climate conditions of the plateau, the environmental friendliness and adaptability of materials are the primary considerations. Low-pollution, biodegradable or recyclable building materials such as weather-resistant composite metals, renewable wood-based materials and low-VOC (volatile organic compound) anti-corrosion coatings are preferred in the design to reduce material aging and the release of harmful substances. Such materials can not only extend the service life of the structure but also reduce the environmental load throughout its entire life cycle.

Ecological compatibility of the material
The material may have potential effects on soil, water sources and living organisms during its use. Through eco-compatibility assessment, the environmental risk level of the material can be quantified, and a dynamic monitoring mechanism can be established. For example, the permeability design of tower base materials can prevent surface runoff concentration and reduce soil erosion caused by freeze-thaw. This approach achieves a dual optimization of material performance and ecosystem stability.

2.2.2. Design of Engineering Transportation Links

Transport route planning
The planning of transport routes should be based on topography and the distribution of ecologically sensitive areas, avoiding plateau wetlands, habitats of rare animals and plants, and marginal ice zones, and minimizing direct disturbances to the surface and biological communities. Optimize transport routes to reduce ecological risks through remote sensing monitoring and GIS analysis technology.

Mode of transport selection
In terms of mode of transport, a comprehensive comparison of the ecological impacts of road, rail and air transport is required. Rail transport has a relative advantage in terms of energy consumption and pollution, while air transport is suitable for efficient material delivery in terrain fragmentation areas. Strike a balance between transport efficiency and ecological conservation through multi-modal coordination and phased transport strategies.

2.2.3. Process Design for Engineering Construction

Optimization of construction techniques
Construction on the plateau adopts low-disturbance, modular, and prefabricated techniques to reduce large-scale excavation and earthwork. For example, prefabricated components are processed in a different location and assembled on-site, which can effectively reduce the damage to the surface ecology during the construction period.

Ecological protection measures during construction
Ecological isolation and transitional restoration of the construction area will be carried out by setting up temporary protective barriers, windbreak and sand-fixing facilities, and vegetation protection belts. After the construction is completed, carry out the original surface reconstruction and vegetation restoration in a timely manner to achieve the simultaneous implementation of engineering construction and ecological protection.

2.2.4. Design for the Operational Phase of the Project

Construction of an ecological monitoring system
During the operation phase, an ecological monitoring system combining remote sensing monitoring, unmanned aerial vehicle (UAV) patrol and ground-based plot observation will be established to track in real time the impact of the project operation on surface temperature, soil moisture and biomes, and form dynamic data support.

Operational optimization strategies
Based on the monitoring results, dynamically adjust the engineering operation parameters, such as the regulation of the tower base drainage system and the optimization of the cable heat dissipation layout, to reduce the long-term disturbance of the engineering facilities to the local ecology and achieve 'low disturbance' control during the operation phase.

2.2.5. Design of the Engineering Maintenance Phase

Ecological considerations for maintenance plans
Maintenance operations should avoid ecologically sensitive periods such as the breeding season of animals and plants and the migratory season of migratory birds to minimize habitat disruption. At the same time, small-sized, low-noise equipment should be given priority to control the secondary impact of maintenance activities on the environment.

Ecological restoration during maintenance
For minor surface damage caused by maintenance, micro-topography restoration, herbaceous plant replanting and soil and water conservation measures should be implemented in a timely manner to achieve an ecological closed loop of maintenance and restoration simultaneously.

2.3. Refinement of Design Principles and Methods

2.3.1. Design principles

The ecological co-construction design of the UHV project on the Qinghai-Tibet Plateau should follow the four following basic principles:

1. **Ecological priority principle**: with ecological safety as the premise throughout the project process, ensure that the project site selection, route planning and construction activities do not cross the ecological red line.
2. **Adapt to local conditions**: adopt regionalized and hierarchical design strategies based on the topography, climate conditions and ecosystem characteristics of the plateau.
3. **Sustainable development**: emphasizing the long-term symbiosis of engineering construction and the ecological environment, taking into account economic, social and ecological triple benefits.
4. **System synergy principle**: to achieve the interactive optimization of engineering technology systems, natural ecosystems and social systems, and to form a multi-dimensional co-construction pattern.

3. Design Strategies for Ecological Co-construction in UHV Corridors

3.1. The Connotation and Extension of the Ecological Co-construction Design Strategy

3.1.1. Interpretation of the Connotation

Ecological co-construction design strategy refers to the construction of large-scale infrastructure with systematic design thinking at its core, viewing engineering construction, ecological protection and social development as a dynamic symbiotic whole, and achieving structural synergy and functional mutual promotion among multiple elements. The core idea is to go beyond the traditional 'engineering-led, ecologically compensated' linear model and shift to the construction of an interactive, circular and regenerative relationship among 'energy - nature - community'.

In the context of UHV transmission projects, ecological co-construction design does not merely focus on ecological restoration or landscape beautification, but rather through design intervention, makes engineering facilities an important part of the regional ecological network. It emphasizes ecological logic as the leading factor in the selection of technical paths, spatial organization patterns, material application and landscape construction, and the co-construction design of natural geographic systems and energy transmission systems to achieve ecological embedding and environmental synergy of infrastructure.

This design concept stems from a rethinking of the way energy infrastructure is built in the context of ecological civilization construction. It requires designers to not only focus on engineering safety and economic benefits when facing complex geographical and ecological conditions but also incorporate ecological adaptability and social sustainability into the design goal system. Ecological co-construction design thus becomes an important theoretical fulcrum for addressing the ecological vulnerability and engineering complexity of the Western UHV corridor and provides a design thinking framework for building energy infrastructure in harmony with nature.

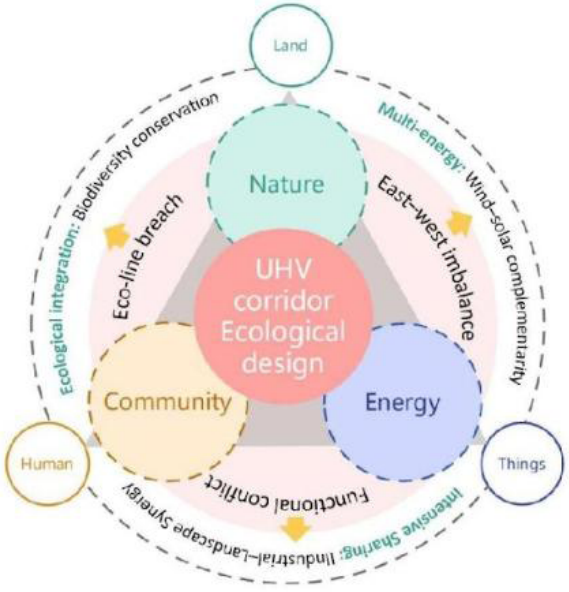

Figure 3: Diagram of the Ecological Co-Construction Design Logic.

3.1.2. Extensional Analysis

The extension of the ecological co-construction design strategy is mainly reflected in the extension and expansion of the three dimensions of space, time and elements, forming a multi-scale and multi-dimensional system framework.

Expansion of the spatial scope

At the spatial level, ecological co-construction design breaks through the limitations of the traditional sense of 'engineering land' or 'construction red line', emphasizing the extension from the transmission project itself to the surrounding ecosystem. The design-thinking extends from 'point facilities' to 'linear corridors' and even 'regional networks', forming a spatial synergy pattern with transmission lines as the framework and ecosystems as the support. Through adaptive design for different landform environments such as mountains, river valleys, grasslands and deserts, the UHV project has been able to reshape ecological connectivity and landscape integrity at the macro level, achieving the transformation from 'engineering embedded ecology' to 'regional symbiotic ecology'.

Extension of the time dimension

In terms of the time dimension, ecological co-construction design not only focuses on ecological protection during the construction period but also attaches great importance to the ecological evolution process throughout the entire life cycle of the project. Its design strategy covers the entire process from pre-site planning, construction, operation and maintenance to decommissioning and reuse, forming a dynamic ecological management mechanism. Especially during the operation and decommissioning phases, through the introduction of design means such as ecological monitoring, adaptive restoration and landscape reuse, the continuous evolution of the ecosystem and the regeneration of the engineering environmental value are achieved, transforming the infrastructure from an 'ecological occupier' to an 'ecological symbiotic'.

Integration of element linkages

At the element level, ecological co-construction design emphasizes the systematic integration of three types of elements: nature, energy and society. Natural elements include topography, water systems, vegetation and biodiversity, while energy elements include power transmission facilities, energy circulation and technology systems and social elements involve community participation, cultural landscapes and local economic development. The interaction among the three constitutes the key network of ecological co-construction design such that nature provides the ecological foundation, energy builds the technological carrier, and society gives humanistic significance and sustainable impetus. Through the collaborative design of multiple elements, the ecological co-construction strategy achieves a balance between technological rationality and ecological ethics.

Overall, the ecological co-construction design strategy is embodied in the idea of system synergy and symbiotic construction, and its extension is manifested in the comprehensiveness of space, the persistence of time, and the integrity of elements. This strategy provides a scientific design framework and operational practice path for the sustainable development of UHV transmission projects in complex ecological environments and promotes the fundamental transformation of infrastructure construction from a single-function orientation to an ecological co-construction orientation.

3.2. Ecological Co-construction Design Strategy

In the construction practice of China's UHV transmission projects, ecological co-construction design has gradually become an important way to coordinate the relationship between infrastructure construction and environmental protection. The core objective is to achieve the organic integration of 'people - land - things' through systematic design intervention.

3.2.1. Integrated Design of Industrial Macrostructures and Corridors

In traditional energy transmission projects, industrial structures such as transmission towers and lines are often prioritized for functionality, which can easily lead to visual landscape fragmentation and ecological space separation. For this reason, designers propose a systematic design concept of 'industrial magnum - corridor integration', emphasizing the formation of complementary structures between industrial facilities and environmental elements such as ecological corridors and transportation corridors through form coordination, spatial layout and material selection. The design concept is to use ecological corridors as a medium to integrate the technical logic of engineering structures with the spatial logic of natural landscapes, thereby establishing a dynamic balance between functional operation and environmental aesthetics.

In practice, some UHV transmission line projects in the West have attempted to reduce the visual and ecological impact of the facilities through lightweight design of tower shapes, extensibility planning of corridor greening systems, and terrain adaptation path design. For example, in mountainous and hilly areas, the design team created a spatial superimposition of technical lines and ecological lines through the coordinated layout of line curves and terrain trends, transforming industrial facilities into part of the landscape structure and significantly enhancing the ecological continuity and landscape value of the corridor as a whole.

3.2.2. Synergistic Design of Ecological Sand Control and Green Electricity

In the arid and semi-arid regions of Western China, the construction of UHV projects is often accompanied by the need for ecological restoration of sandy land. The ecological sand control and green power co-design model is centred on the energy - ecology dual cycle, and through the clean power resources provided by the UHV transmission system, it supports ecological governance projects such as photovoltaic sand control and artificial vegetation planting. This model breaks through the traditional one-way engineering construction thinking and transforms energy infrastructure into the power source for regional ecological reconstruction.

Take the UHV project in a typical desert area in the west as an example. Distributed photovoltaic systems are installed along the transmission lines to provide stable energy support for windbreak, sand fixation and vegetation restoration projects. At the same time, precise and sustainable ecological restoration is achieved through green electricity-driven intelligent irrigation systems and monitoring platforms. Practice shows that the design pattern, while achieving energy conversion benefits, effectively promotes regional biodiversity restoration and soil structure improvement, forming a mutually reinforcing mechanism of 'energy utilization - ecological governance - environmental restoration'.

3.2.3. Soil Remediation and Landscape Sharing Design

UHV projects cause significant disturbance to the surface during construction and operation and maintenance, especially in areas such as tower foundations and construction passages, which can lead to land degradation and ecological fragmentation. The proposal of the soil remediation and landscape sharing design model aims to achieve the regenerative utilization of land resources through the simultaneous governance of engineering and ecology. The design concept follows the path of 'restoration - regeneration – sharing', transforming disturbed land into shared spaces with ecological, educational and social functions through a comprehensive strategy of soil improvement, vegetation reconstruction and landscape reshaping.

In some of the pilot projects, the restored transmission corridor areas were re-planned as ecological display belts or agricultural demonstration sites. The design team created 'composite landscape units' with both ecological restoration and landscape education functions through vegetation community reconstruction and terrain micro-modeling. Such practices not only restore soil health and ecological functions but also promote local society's re-recognition of the environmental value of engineering, providing a new paradigm for the symbiosis of UHV projects and regional environments.

4. Conclusion

In today's world where sustainable development is being vigorously promoted, the ecological co-construction design of energy infrastructure projects should be based on systems and sustainability, with ecological priority as the core orientation, to ensure that the entire process of the project does not cross the ecological red line. This ensures that they adhere to the principle of adapting to local conditions, formulating regionally targeted stratified design strategies based on the unique topography and implementing the concept of sustainable development and achieve a coordinated unity of economic, social and ecological benefits and follow the principle of system synergy to promote deep interaction and optimization among engineering and technology systems, natural ecosystems and social systems, and build a multi-dimensional co-construction pattern that is functional, ecological and social. The refinement of this design principle not only provides an operational guiding framework for energy engineering but also explores a new path that takes into account development and ecological protection for infrastructure construction in ecologically sensitive areas.

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Rethinking Design Education: From Normative Models to Regenerative Pedagogies

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Abstract

In a time of ecological, social, and cultural transitions, design education must move beyond linear and normative paradigms rooted in Eurocentric and market-oriented models. This paper explores how design pedagogy can evolve to cultivate critical, responsible, and context-aware designers capable of acting within systemic complexity. Drawing on theoretical contributions from Norman, Bass and Manzini, the research proposes a regenerative and political approach to education, where learning becomes a site of deconstruction, dialogue, and collective imagination. The study introduces *Norma Mitica – Designing the Future in a Plural World*, an experimental, non-hierarchical framework combining theory, storytelling, and hands-on activities to expose implicit norms and promote inclusive and ethical practices. The project aims to foster a shift in both educational culture and professional identity, positioning design as a transformative act for social justice, plurality, and sustainable futures.

Keywords: Critical design, design education, plural futures, regenerative pedagogy, social responsibility.

1. Introduction

In recent decades, design has undergone a profound transformation: from a discipline primarily oriented toward the production of objects and aesthetic-functional solutions, it has evolved into a strategic practice capable of intervening in social, cultural, and ecological systems (Manzini 2015). Within this context, design education plays a crucial role: it is through educational pathways that the skills, perspectives, and responsibilities of future designers are shaped.

However, much of design education remains structured around paradigms developed throughout the twentieth century, still focused on the production of outputs, and is now inadequate to address the complexity of contemporary issues and the need to account for social, cultural, and ecological impacts (Rowe 2025).

The global landscape is characterized by deep and interconnected transitions: ecological and climate crises, social and demographic transformations, and cultural and technological shifts all demand new forms of design thinking and action. If understood as a situated, relational, and pluriversal practice, design can significantly contribute to the construction of sustainable and plural futures. As Noel (2023) observes, a pluriversal design education prepares designers to engage with the diversity of contexts, to facilitate community participation, and to shape shared values through inclusive and context-sensitive design processes.

Yet these potential benefits remaining untapped if educational institutions continue to operate according to linear, transmissive, and functionalist models conceived for a socio-economic system that no longer exists.

This gap between what design could become and what is still being taught lies at the heart of a growing academic debate. Norman and Meyer (2022) emphasize that current curricula remain centred on the object and aesthetics, often neglecting systemic, ethical, and social competencies. Similarly, Bass (2020) describes a "crisis of meaningfulness" in higher education, pointing to the need for reforms that enable transformative learning processes and critical engagement with reality. Within the field of design, this necessity translates into a specific urgency: to radically rethink what it means to "educate a designer" today.

The persistence of Eurocentric and universalist models, the vertical organization of knowledge, and the marginalization of non-Western epistemologies are among the structural issues that hinder the evolution of design education. In a world characterized by cultural plurality and systemic interdependence, such models are not only inadequate but also risk perpetuating dynamics of exclusion and inequality. Rethinking education thus means questioning the implicit norms that regulate the production and transmission of design knowledge.

In light of these considerations, this paper aims to explore the role of education as a strategic lever to transform design into a critical, responsible, and plural practice. The research question guiding this work is: **How can design education evolve beyond transmissive and normative models to enable designers capable of acting within contemporary complexity?**

To address this question, the paper presents *Norma Mitica*, an experimental educational format developed to deconstruct conventional design paradigms and foster a reflective, ethical, and inclusive approach to design learning.

The objective is to contribute to the international debate on the reform of design education by offering theoretical and practical insights for a regenerative pedagogy, one capable of accompanying design in its disciplinary and social redefinition. In this sense, education is not merely a space for transmitting skills but a political and cultural ground on which to imagine and construct new ways of inhabiting the world.

The paper is structured as follows. Section 2 traces the historical evolution of educational models in design, analyzing their principles and transformations. Section 3 highlights the limitations and criticalities of traditional paradigms, exposing the gap between present needs and consolidated teaching practices. Section 4 explores emerging theories and perspectives that propose more inclusive, systemic, and transformative approaches. Section 5 presents and discusses *Norma Mitica*, a pedagogical experiment aimed at deconstructing the implicit norms of design and exploring new forms of critical and collaborative learning. Finally, Section 6 examines the limits and opportunities of the project and the broader research process, leading to the concluding reflections developed in Section 7.

2. Educational Models in Design: History, Principles, and Contemporary Challenges

Design education, as it took shape during the twentieth century, was moulded by epistemological and cultural paradigms that emerged within an industrial and modernist context. The main centres of training, from the Bauhaus in Weimar and Dessau to the Hochschule für Gestaltung in Ulm and the Anglo-Saxon schools, based their teaching on core principles: the centrality of form and function, the idea of a linear and rational design process, the separation between theoretical and practical knowledge, and a generalized notion of the user conceived in abstract and neutral terms, reflecting the modernist tradition described by historical authors (Droste 2002; HfG Ulm Archive 1968; Dormer 1990).

These principles enabled design to establish itself as an autonomous discipline, equipped with rules and methodological tools that strengthened its professional identity. However, as Margolin (2002) notes, such autonomy also entails implicit values and norms that reflect specific cultural contexts rather than a universal neutrality.

The educational model that emerged in the postwar period responded to the needs of an industrial and standardized production system: training aimed to prepare professionals capable of meeting the demands of industry, developing functional products, and supporting market evolution. At the same time, the cultural dimension of design was interpreted mainly in aesthetic terms, emphasizing form as the synthesis of rationality and beauty (Droste 2002; Dormer 1990).

While these models provided solid methodological foundations and a clear professional identity, they now reveal evident limits when confronted with contemporary complexity: they do not fully integrate social, cultural, and ecological dimensions, nor do they foster designers' ability to understand systems, relationships, and plural contexts. These shortcomings define a clear educational gap: what is missing in current design curricula to prepare designers capable of addressing complex, uncertain, and interconnected problems?

3. Limits and Criticalities of Traditional Models (The Gap)

Despite the central role that design education has played in shaping the disciplinary and professional identity of twentieth-century designers, these models now reveal increasingly evident structural and cultural limitations. The contemporary context, marked by systemic complexity, cultural plurality, and rapid socio-technological transformations, requires designers to acquire competencies radically different from those of the past. Yet pedagogical and institutional practices still struggle to keep pace with these changes.

At a global level, the discipline itself is undergoing a process of critical and political deconstruction (van Amstel et al. 2022; Ansari et al. 2018, 2021; Costanza-Chock 2020; Escobar 2018; Keshavarz 2019; Lupton 2021), questioning historically rooted paradigms and opening up profound reflections on the very meaning and aims of design education. Within this framework, the educational gap becomes evident: what is lacking today is not merely the transmission of technical expertise but the cultivation of critical, relational, and systemic tools capable of forming designers who can read, interpret, and transform complex realities.

3.1. Transmissive Pedagogy and the Passive Role of the Student

One of the most deeply rooted limits within design institutions is the persistence of a transmissive pedagogical paradigm, in which the teacher acts as the sole bearer of knowledge and the student as a passive recipient. Paulo Freire famously described this dynamic as a "banking education," a model that neutralizes students' critical capacities and deprives them of their role as co-producers of knowledge (Freire 1970).

In design education, this approach translates into curricula focused on reproducing established solutions and adhering to predefined aesthetic or functional standards. Assessment tends to reward conformity to implicit norms rather than the ability to explore alternative scenarios, reducing design to a formal exercise and limiting its transformative potential. As Riccini (2023) notes, such a model often lacks critical renewal, perpetuating relational dynamics marked by competition, oppression, and inequality (Sfligiotti 2023).

3.2. The Illusion of the Universal User

A second limitation lies in the implicit assumption of a neutral, universal user, a concept rooted in modernist paradigms. This supposedly inclusive model is in fact built upon Eurocentric, masculine, and normative perspectives that have historically excluded non-majoritarian identities, bodies, and cultures.

As Sasha Costanza-Chock observes, traditional design "works well" only for certain social groups and tends to reproduce structures of exclusion rather than challenge them (Costanza-Chock 2020). When such dynamics remain unexamined in educational settings, students internalize an idea of design as a neutral and universal practice, devoid of political awareness. This prevents them from developing a critical stance toward the mechanisms of power, representation, and privilege that shape every design process.

3.3. Fragmentation of Knowledge and the Crisis of Complexity

Another critical issue is the disciplinary fragmentation of curricula. The strict division between theory and practice, between product and communication design, between research and project work, once responded to the needs of the industrial model of the twentieth century, but today it proves increasingly ineffective.

Contemporary design operates within complex systems where technology, ecology, politics, and culture are deeply interconnected. To act within such contexts, designers must develop tools that enable them to read and transform socio-material systems, going beyond traditional technical competencies. As Tony Fry argues, the designer of the twenty-first century must be able to "prefigure futures" rather than simply solve immediate problems (Fry 2009). Fragmented approaches, instead, hinder the development of systemic thinking and limit students' capacity to elaborate integrated design strategies.

3.4. Responsibility and Projective Reflexivity

Many educational programmes continue to prioritize project efficiency over reflexivity and social responsibility. Students are often trained to "find solutions" rather than to question the premises of the problem or to consider the socio-ecological consequences of their design choices.

Ezio Manzini emphasizes that design must evolve from a solution-oriented practice into a transformation-oriented one, capable of facilitating collective and sustainable change (Manzini 2015). Reflexivity, understood as the ability to situate one's design decisions within a historical, political, and ecological context, remains marginal within most curricula. This deprives future designers of critical tools to understand the systemic impact of their work and to assume an active role in processes of social and environmental transformation.

3.5. Democratization of Skills and New Challenges for Education in the Generative AI Era

A further dimension of the educational gap concerns the shifting value of technical know-how. In the past, mastery of tools represented a distinctive barrier and defined the professional identity of the designer; today, such skills are increasingly accessible through advanced software, digital platforms, and online learning (Buchanan 2019; Lupton 2021; Lorusso 2022).

The advent of generative artificial intelligence has accelerated this transformation, radically redefining design practice and reshaping the relationship between ideation and production. Operations once central to the designer's craft, such as generating images, developing forms, or creating prototypes, can now be automated, shifting the focus from *making* to *deciding*. In this scenario, technical expertise is no longer the primary measure of professional quality.

As Fry (2011) argues, the true challenge of education lies not in teaching operational skills but in cultivating designers capable of orienting their choices within a complex and interdependent world. From this perspective, what distinguishes a contemporary designer is the capacity to pose meaningful questions, interpret socio-cultural contexts critically, mediate between technological and ethical demands, and imagine desirable futures.

Recent studies confirm that AI is redefining the competencies required by the design profession, moving the focus from mere technical execution to the ability to orchestrate complex systems, integrate multiple forms of knowledge, and act with critical awareness (Zhang et al. 2025; *Students' Perceptions* 2025). If these transformations are accepted as a premise, design education must adapt accordingly: it is no longer sufficient to train technical proficiency, what is needed is the cultivation of systemic thinking and ethical responsibility as core competencies for the future of design.

4. Theories and Emerging Perspectives

In recent decades, the growing awareness of the social, ecological, and political complexity of the contexts in which design operates has stimulated the development of theoretical perspectives that challenge traditional educational models. Although heterogeneous, these perspectives share a common goal: to redefine the role of the designer and of design education by centring relationships, context, plurality of knowledge, and the transformative dimension of design practice.

4.1. Human-centred and Humanity-centred Design

A first relevant approach is *Human-Centred Design (HCD)*, which places the user at the centre of the design process and emphasizes understanding human needs and behaviours (Norman). However, more recent perspectives, such as the so-called *Humanity-Centred* approach, expand this concept. This framework integrates social, cultural, and ecological considerations, urging designers to account for the impact of their actions on entire communities and ecosystems (Norman 2013; Norman and Stappers 2015).

4.2. Transformative and Radical Education

Design education can be conceived as a space for transformative learning, inspired by models of critical and radical pedagogy. Randy Bass (2020) underscores the importance of training designers capable of critically reflecting on their role and the impact of their actions, while Paulo Freire (1970, 2011) and bell hooks (2020, 2022) invite educators to deconstruct transmissive paradigms by promoting active participation, empathy, and care within the classroom. These approaches view students not as passive recipients but as co-producers of knowledge, capable of questioning norms and envisioning new scenarios.

4.3. Participatory and Situated Design

Participatory Design emphasizes collaboration with communities and the co-creation of solutions relevant to real contexts (Smith & Iversen 2018). In parallel, perspectives such as *situated* and *relational design* (Manzini 2015; Escobar 2018) argue that design cannot be detached from the social, cultural, and material contexts in which it takes place. From this viewpoint, design education must train students to understand complex systems, relationships, and interdependencies, fostering inclusive practices that are sensitive to the specificities of places and communities.

4.4. Pluriversal Design

A further contribution comes from the experiment conducted by Lesley-Ann Noel (2020, 2022) during PIVOT 2020, which proposed a *pluriversal pedagogical model* inspired by the principles of Arturo Escobar (2018). The idea of *pluriversal design* invites us to regard design as an activity deeply influenced by specific cultural contexts, power relations, and positionalities. Education, therefore, should be situated, decolonial, and capable of valuing the plurality of knowledges, opening spaces for critical, collaborative, and transformative design practices (Abdulla 2017; Noel 2020).

4.5. Decolonizing Design Education

Design school curricula remain often anchored in Eurocentric and modernist paradigms that present Western knowledge as universal while relegating other traditions to marginal positions (Ansari 2018, 2021). *Decolonizing education* thus means questioning the epistemic assumptions of design itself: Who defines the canons? Who has a voice in decision-making processes? Which perspectives are systematically excluded? As Escobar (2018) suggests, a decolonial pedagogy does not aim to replace one paradigm with another but to create spaces of negotiation where different systems of knowledge can dialogue, contaminate one another, and coexist, opening design to new imaginaries and plural visions of the future.

Rethinking design education in this direction means going beyond a mere update of curricula: it entails repositioning the entire discipline as a lever for building possible futures. It is within this perspective that the *Norma Mitica* project is situated, a concrete experiment translating these theories into educational practices and tools for transformative learning.

5. *Norma Mitica*: A Device to Defuse Norms

Norma Mitica is an academic discipline conceived to integrate the curricula of Italian design schools. It arises from the need to educate designers capable of addressing contemporary challenges, going beyond mere technical competence. In a context where know-how is easily accessible, what distinguishes a good designer is the ability to understand context, interpret complexity, and act with social and ethical awareness.

Norma Mitica is presented as a concrete case study within the *Didactic Diagram* of ISIA Roma Design, focused on design activism. Its objective is to guide students through a critical reflection on their role in contemporary society, by analyzing internalized norms and promoting a decolonized, feminist, non-ableist, and queer history of design, thus encouraging an inclusive and transformative design practice.

5.1. International Context

The methodological approach of *Norma Mitica* aligns with an expanding international trend. Prominent institutions such as the Royal College of Art, University of the Arts London, Pratt Institute, School of the Art Institute of Chicago, and Rhode Island School of Design are incorporating ethical frameworks centred on social justice, activism, and sustainability, in order to orient design practice toward systemic responsibility.

5.2. Objectives and Design Intentions

The primary objective of *Norma Mitica* is to deconstruct established design conventions by promoting a critical understanding of the surrounding context.

The discipline unfolds in three interconnected phases. In the first phase, *the World*, students are guided to develop a critical perspective on the social environment in which they operate, learning to interpret the culture of their time, recognize inequalities and privileges, understand emerging needs, and value excluded narratives and practices.

In the second phase, *the Self*, the focus shifts to the individual: students reflect on their own role, cultivate self-awareness, and understand how the personal is intrinsically political.

In the third phase, *Design*, students translate their critical understanding into concrete actions: applying ethical principles to design, adopting an activist perspective, considering design as an expression of collective identities, and addressing inclusivity and accessibility as opportunities for social innovation. This final phase represents the ultimate aim of the discipline, connecting awareness of the world and self-reflection to meaningful design practice (see Figure 1).

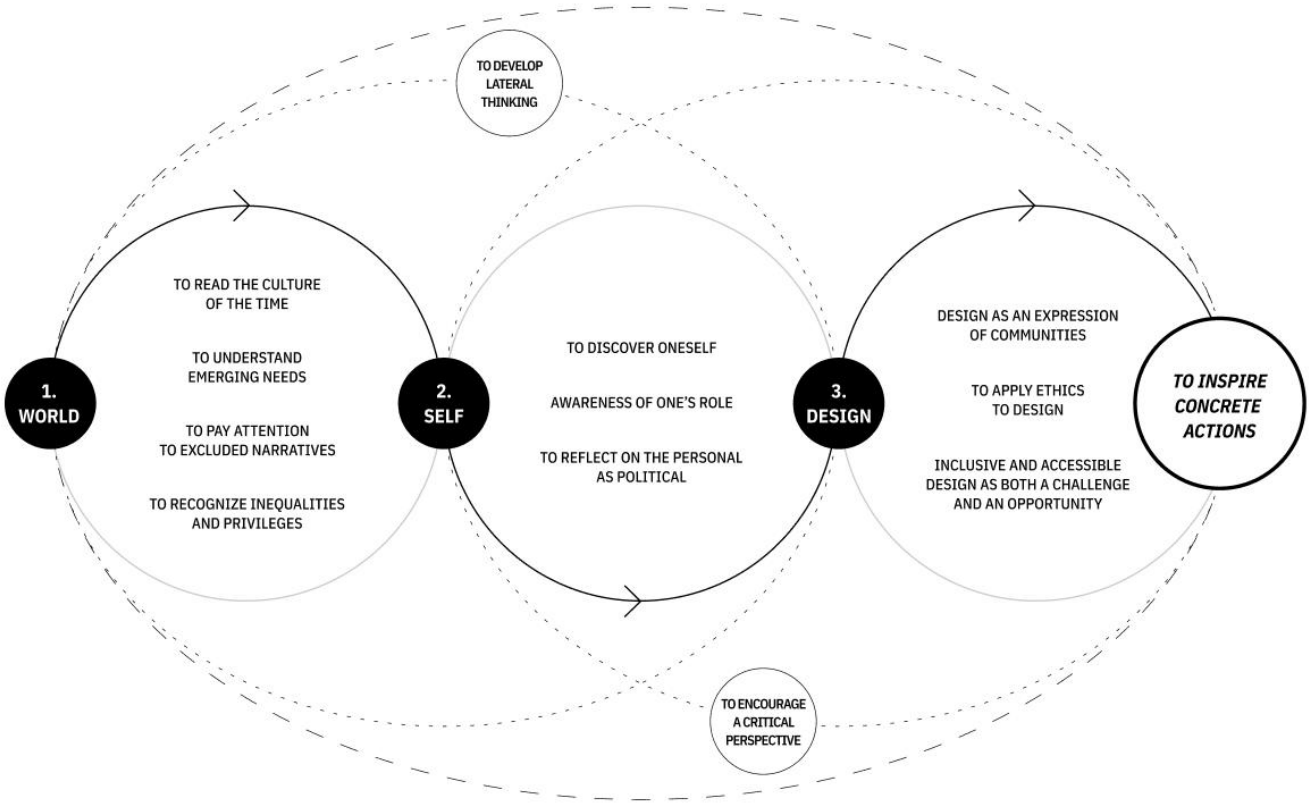

Figure 1: Schematic representation of *Norma Mitica*'s objectives and structure, illustrating the three phases: developing a critical perspective on the world, self-reflection, and applying insights in design, with the final goal of inspiring concrete actions. Credit: Giovanna Merialdo

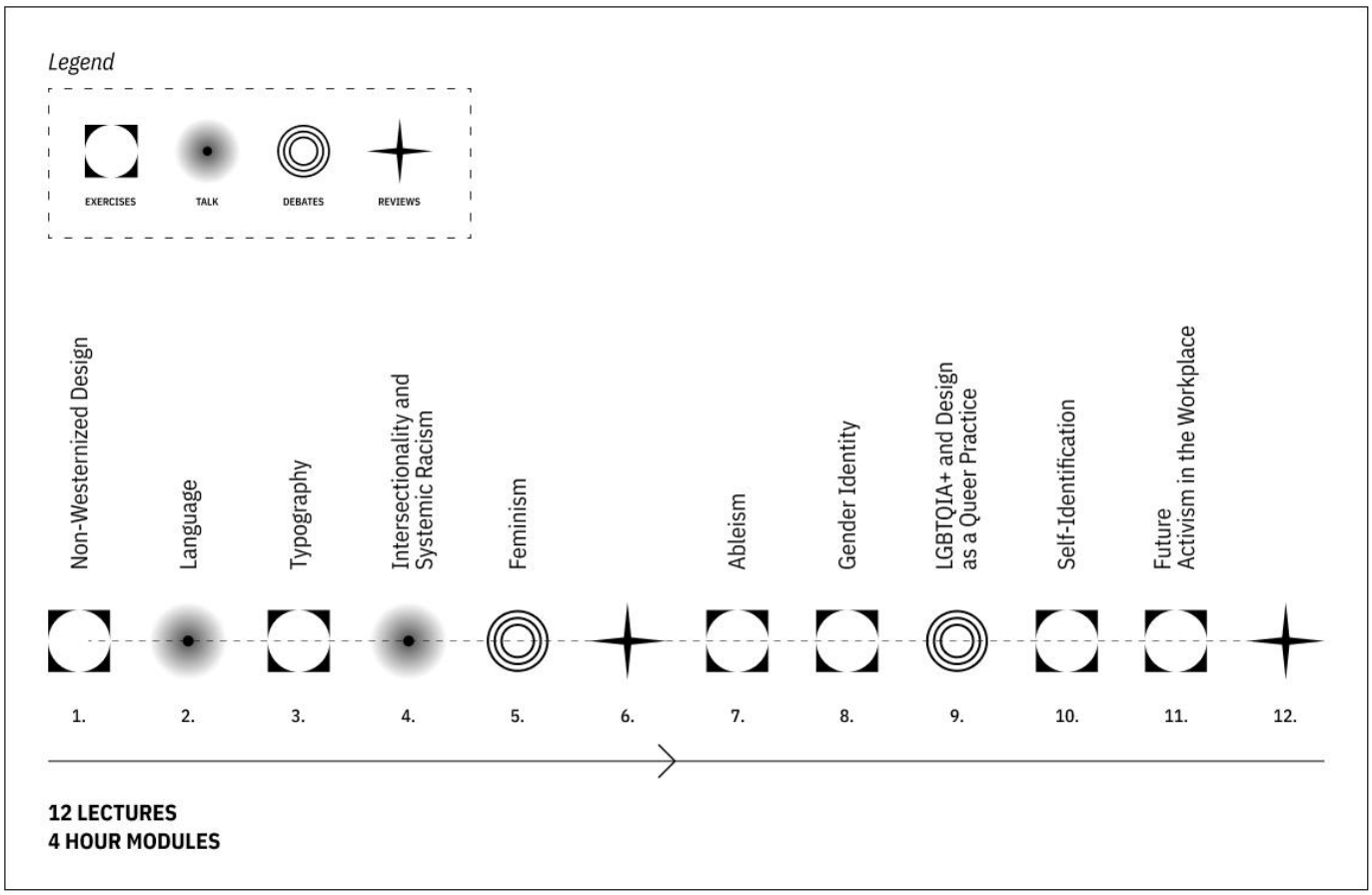

Figure 2: Schematic representation of the twelve modules of *Norma Mitica*, each corresponding to a four-hour lesson. The diagram illustrates the thematic progression of the discipline, showing for each module the topic addressed and a specific symbol referring to the main pedagogical tool employed — debate, talk, practical exercise, or review — thus visualizing the integration of theoretical and experiential components. Credit: Giovanna Merialdo

5.3. Structure of the Discipline and Produced Outputs

The *Norma Mitica* course is organized into twelve teaching modules, each lasting four hours. The structure follows a sequential framework that balances theoretical acquisition with practical application.

5.3.1. Modular Contents

The course consists of ten modules dedicated to key themes of critical and inclusive design, aimed at deconstructing established narratives and practices. The addressed topics include: Non-Westernized Design; Language; Typography; Intersectionality and Systemic Racism; Feminism; Ableism; Gender Identity; LGBTQIA+ and Design as a Queer Practice; Self-Identification ("The personal is political"); and Future ("Activism in the workplace"). Two additional modules are devoted to project reviews – one at mid-course and one before the final presentation – to support the development and assessment of the students' work.

Each module follows a recurring didactic structure: the first two hours are devoted to lectures introducing theoretical concepts, while the remaining time involves practical activities, debates, and talks with external guests, aimed at fostering active participation (See Figure 2).

5.3.2. Project Output

The didactic project culminates in the production of two complementary outputs, designed to expand and institutionalize the *Norma Mitica* approach: a printed volume and a digital platform.

The volume serves as both a theoretical and practical apparatus, collecting the ten key topics accompanied by design references, educational worksheets, and ten interviews with experts in the field (such as Vera Gheno). Notably, its graphic design itself constitutes an exercise in normative deconstruction: from colour palette to grid system and symbolic structure, the book aims to dismantle established visual norms, encouraging alternative readings and stimulating critical creativity (see Images 1-3).

The digital platform, accessible via QR code, complements and amplifies the printed volume by providing additional interactive content, such as thematic insights, technical sheets, and experiential activities, ensuring dynamic and multimedia access to the course material.

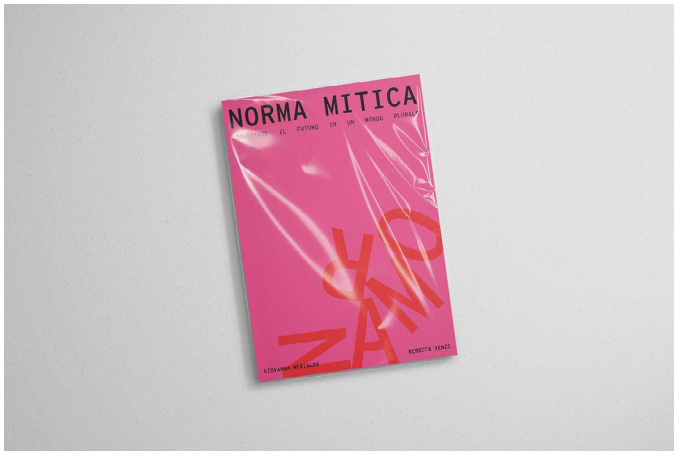

Image 1: Front cover of the *Norma Mitica* printed volume. Credit: Giovanna Merialdo

Image 2: Open view of the *Norma Mitica* volume in an outdoor setting, showing pages being flipped to highlight internal content and layout. Credit: Giovanna Merialdo

Image 3: Close-up detail of an internal page of the *Norma Mitica* volume, illustrating layout, typographic choices, and graphic elements. Credit: Giovanna Merialdo

5.4. Experimental Methodology

The preliminary experimental phase of *Norma Mitica* was conducted through the implementation of two pilot lessons at ISIA Roma Design. The intervention involved a differentiated sample of students: a four-hour session with the third-year undergraduate class, and a two-hour session with the second-year master's class.

Each teaching module intentionally integrated a blended learning approach: a frontal component for introducing key concepts, open discussions to foster critical exchange and collective reflection, and practical exercises.

The primary aim of the experimentation was observational in nature, to map students' reception of the themes, recording levels of interest as well as emotional and cognitive responses (such as engagement or potential discomfort). The inclusion of samples from different academic years allowed an assessment of the most appropriate stage for introducing the discipline and an analysis of differences in students' capacity for critical elaboration.

The results of these qualitative observations formed the basis for a subsequent structured feedback collection, carried out through an online questionnaire. The critical discussion of both observational and structured data made it possible to evaluate the effectiveness of the tools and methods employed, significantly contributing to the definition of the guidelines and strategies for future applications of the discipline.

5.5. Details of the Pilot Lessons and Exercise Outputs

The pilot lessons of *Norma Mitica* integrated lectures with practical exercises, discussions, and reflective activities, transforming theoretical content into concrete and immersive experiences. The core of the experimentation consisted of exercises designed to stimulate students' ability to question established norms, develop critical, political, and inclusive awareness, and connect theory with practice.

1. Breaking Out of the Mythical Norm

This activity operated on two levels:

a) **Rules of graphic design:** students were invited to identify a fundamental rule of graphic design (e.g., visual hierarchy, compositional grids, typographic use) and to "desert" it, by performing a radical reinterpretation. To broaden cultural perspectives, the exercise required the choice of a non-Western designer as a reference, introducing models and perspectives often excluded from historical canons.

b) **Visual language and stereotypes:** a second part of the activity focused on language. Students were asked to modify the graphic representation of a musical text by acting on typography, composition, and colour, without altering its verbal meaning. The exercise empirically demonstrated how visual grammar can convey implicit stereotypes or actively promote inclusivity.

2. Disabling experience

The second exercise imposed a physical constraint: students were required to continue developing their project without using their dominant hand. This approach encouraged embodied learning, prompting reflection on the role of the body and gesture in the design process, and questioning the traditional conception of ability as a prerequisite for design. The activity fostered meaningful discussions about exclusion, diversity, and implicit barriers within design practice.

3. Systemic self-analysis

The third exercise invited students to construct a personal map of their design trajectory, analyzing significant relationships within the design field, cultural and intellectual influences, relevant formative experiences, skills acquired or to be developed, and future goals. This exercise connected theoretical concepts – power, norm, identity, marginality – to individual experience, fostering a more conscious understanding of one's role as a designer.

The tangible outputs produced – posters, collages, illustrations, and personal maps – constituted direct empirical material crucial for reflection on norms, language, and inclusivity. These artifacts not only consolidate learning but also serve as a methodological archive for the discipline and future evaluation stages (see Image 4).

Image 4: Selection of posters produced during the *Norma Mitica* pilot lesson, representing outcomes of the "Breaking out of the Mythical Norm" exercise. The image illustrates students' exploration of inclusive visual languages through experimental reinterpretations of graphic conventions. Credit: Giovanna Merialdo

5.6. Evaluation and Feedback

To systematically evaluate the effectiveness of the pilot lessons and gather operational insights for potential curricular implementation, a structured feedback process was conducted. The tool employed was an online questionnaire administered via Google Forms immediately after the teaching sessions. The reference sample consisted of the entire third-year class of the undergraduate Design programme, involving *N* = 17 participants, representing 100% of the students attending the module.

5.6.1. Research Tools and Objectives

The questionnaire comprised 18 items, three open-ended and the remainder multiple-choice, and pursued the following analytical objectives:

- Assess students' perceptions of the strengths and weaknesses of the current curriculum.
- Measure the relevance and perceived importance of the topics covered for both academic and professional development.
- Identify the themes considered most stimulating and significant.
- Evaluate the balance between theory and practice (practical exercises versus conceptual understanding).
- Collect critical observations and targeted suggestions for improving the course proposal.

5.6.2. Summary of Key Findings

The analysis of the results made it possible to extract several insights supporting the relevance and necessity of the discipline:

1. The main strengths of the current educational model lie in the acquisition of transversal skills, while its most significant weaknesses concern the limited connection with the professional world and the lack of content related to social and contemporary issues. This finding analytically confirms the relevance of the approach proposed by *Norma Mitica*, which aims to broaden the critical perspective and to include more complex design dimensions.

2. The topics that aroused the greatest interest were the history of non-Western design and the reflective moments focused on the future and on professional identity ("who I am and who I will become"). This emphasis highlights the participants' desire for a more inclusive and plural design knowledge, distinctly oriented toward the reflective and personal dimensions of the profession.

3. The practical exercises were considered very useful by most participants for understanding theoretical concepts, although they were not perceived as essential for overall learning. Among the quantitative critical points, the most recurrent was the perception of insufficient time to explore the contents and to develop the activities. This observation represents a fundamental element in view of a future implementation of the discipline, suggesting the need for a longer timeframe or a more balanced distribution of the sessions.

5.6.3. Qualitative Analysis

The open-ended responses provided valuable qualitative insights. Many students emphasized the importance of a course capable of connecting complex contemporary issues with design practice, as reflected in one comment: *"I greatly appreciated the intent behind this project and strongly identify with the need to integrate ISIA's curriculum with a course that addresses contemporary issues and relates them to design practice."* Another student highlighted the course's potential to *"broaden the designer's perspective, those who work with society and therefore need to understand it in all its facets."*

Responses to the question concerning designers' responsibilities also indicated a growing awareness of the social role of design. As one respondent noted: *"The designer becomes a creator of codes and languages addressed to society, which in turn form a culture."* These reflections confirm the transformative potential of an educational approach aimed at revealing the political, cultural, and social dimensions of design.

Overall, the results of the questionnaire confirmed the relevance and formative potential of the proposed experimental path, emphasizing the importance of integrating broader social and cultural themes into the curriculum, fostering moments of critical reflection, and strengthening the connection between academic knowledge and professional practice.

6. Limits and Possibilities

The results emerging from the *Norma Mitica* experimentation enable a critical reflection on the initial research question and allow for its more conscious reformulation in light of empirical evidence: *How can a regenerative pedagogical approach contribute to redefining the designer's identity and role in contemporary society?*

The experience of the pilot lessons suggests that such transformation becomes possible precisely when education abandons a transmissive model, centred on the production of standardized competencies, in favour of a critical, dialogical, and plural paradigm. When the implicit norms of design knowledge are rendered visible and questioned, learning becomes a political space: no longer a mere acquisition of tools, but a practice of awareness, agency, and transformation.

From this perspective, the designer ceases to be merely a "problem-solver" and becomes a facilitator of processes, a cultural agent capable of building connections, giving voice to marginalized instances, and imagining new ways of inhabiting the world. The experimentation demonstrated how uncertainty can become fertile ground for generating new questions, how listening fosters deep contextual understanding, and how collaboration constitutes an indispensable design competence.

Despite the significant positive indications, the experiment presents notable methodological limitations. The short time frame and the limited number of participants (*N* = 17) do not allow for a full assessment of the long-term impact of the pedagogical model nor for the generalization of its results. Moreover, the experience remained confined within the academic institution, without involving external communities or real-world contexts. Integration with real and social contexts would represent an essential testing ground for a genuinely transformative pedagogy and a necessary step toward overcoming the implicit barriers of the academic environment.

Nevertheless, these limitations simultaneously open up promising future scenarios. The full structural integration of the discipline into academic curricula, the co-design of content with students, and the activation of hybrid educational pathways in collaboration with social, cultural, or territorial organizations are directions that could decisively strengthen the project's effectiveness and consolidate its long-term transformative potential.

7. Conclusion

The research and experimental journey of *Norma Mitica* confirms the urgency of rethinking design education as a regenerative and political practice, one capable of addressing the complex challenges of the present (Escobar 2018). Far from being a mere transfer of technical knowledge, the educational process becomes a space for deconstructing implicit norms, opening up to plural perspectives, and exercising collective imagination (Freire 1970).

The transversality of themes such as power, language, marginalization, and identity emerges as a fundamental element, not only to enrich the designer's cultural background but also to redefine the very meaning of design practice (Costanza-Chock 2020; Lupton 2021). In this light, the value of uncertainty, doubt, and the capacity for listening are no longer ancillary, but constitutive of a new way of designing, one grounded in relationship and responsibility.

An educational model that activates these processes can cultivate designers who are aware of their political and cultural role, capable of constructing new narratives, new forms of relationship, and new ways of inhabiting spaces. The research thus opens toward a vision of education as a practice of care, social justice, and the construction of possible futures. Educational institutions can become spaces of experimentation and transformation, capable of generating tangible social impact and fostering the emergence of a new generation of designers who are more conscious, inclusive, and responsible.

This work stands as an invitation to expand the debate and to collectively build new educational paradigms founded on collaboration among educators, students, institutions, and communities. Only through such collaboration will it be possible to imagine and construct a future for design that is not only functional and innovative, but also just, plural, and profoundly human.

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Rethinking Design from Within: An Introduction to the Symbiotic Design Framework

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Abstract

This paper introduces the Symbiotic Design Framework (SDF), a theoretical and operational model for reorienting contemporary design practice in response to escalating global crises. It argues that a fundamental paradigm shift is necessary, moving design from a discipline often complicit in unsustainable and unjust systems to one that is self-aware, ethically grounded, and systemically potent. The paper is structured in three parts. Part 1 establishes the philosophical imperative for this shift, confronting design's historical complicity within the Capitalocene, asserting its inescapable political nature, and proposing an ethical compass grounded in the pursuit of collective flourishing (Eudaimonia). Part 2 outlines the framework's theoretical foundations, tracing its roots in systems thinking and establishing its core logic in the biological theory of autopoiesis — the self-production of living systems — which is applied here to understand design as a dynamic social system. Part 3 details the framework's operational anatomy, presenting its seven interdependent components (Human, Commission, Observations, Procedures, Partners, Technological, and Outcomes) and the logic of symbiosis used to diagnose and guide their interrelationships. The SDF is ultimately presented not as a rigid methodology but as a critical stance for fostering a more conscientious, liberatory, and symbiotic design practice.

Keywords: Capitalocene critique, decolonial design, design ethics, pluriversal design, symbiotic design, sustainable regenerative design, systems thinking design.

Introduction

We practice our craft on a planet profoundly altered, navigating a moment defined by a tangled knot of intersecting crises — ecological, social, and political. Within this context, the institutional dogmas and theatrical lies of 'neutral' design that have long kept our discipline busy while the house smoulders are no longer tenable. The Symbiotic Design Framework (SDF) emerges from over a decade of sustained research into this predicament (Raineri 2020), born from a conviction that we must destroy design's actual model to build a better world in the meantime (Raineri 2025). It is a response to the urgent need for a fundamental reorientation of design, moving it beyond a mere problem-solving technique or an engine of novelty toward a self-aware, ethically grounded, and systemically potent practice, rooted in diverse realities (Raineri 2002).

This paper will argue that such a transformation requires a new way of seeing and acting — a new theoretical background for acting in the world. It posits that by understanding the design discipline itself through the lens of living systems, specifically by adopting the biological theory of autopoiesis (self-production), we can unmask the mechanisms by which it perpetuates its own norms and, more importantly, identify the levers for its conscious and ethical redirection (Raineri 2020). The SDF is therefore presented not as a prescriptive methodology or a set of "five steps to impact," but as a critical stance and a navigational compass aimed unapologetically at Eudaimonia: the well-being for all living entities on this planet.

The Symbiotic Design Framework is not a theoretical invention but the result of a decade-long inquiry to understand design not as a static toolkit, but as a living, adaptive system. Its foundation was forged through doctoral research that systematically investigated design through the biological lens of autopoiesis, proposing that design, as a discipline, is a self-creating and self-maintaining entity. This hypothesis was not merely asserted but rigorously tested through a multi-stage empirical process that included a deep analysis of over one hundred historical and contemporary definitions of design, an extensive exploratory review of the discipline's theoretical traditions, and a global survey of over 360 designers to map the collective understanding of their practice. The initial findings and the nascent framework were then further tested, validated, and refined through a series of international workshops, presentations at academic symposia, and extensive dialogues with practitioners and educators during events such as World Design Capital (WDC)® Valencia 2022. This iterative process of theoretical modeling, empirical investigation, and collaborative refinement ensures the SDF is not an abstract ideal but a framework deeply grounded in both the philosophical underpinnings and the lived reality of contemporary design practice.

The argument will unfold in three parts. First, we will establish the philosophical imperative for a symbiotic design by confronting the discipline's historical complicity in the crises of the Capitalocene, asserting its inescapable political nature, and articulating its core ethical compass. Second, we will delve into the theoretical foundations of the framework, tracing its intellectual lineage in systems thinking and cybernetics and detailing its central logic of autopoiesis. Finally, we will outline the operational anatomy of the framework, deconstructing the design process into seven interdependent components whose relationships can be diagnosed and guided toward more symbiotic states. This is a call to do the harder work of thinking systemically and acting ethically, to feel the floor shift under our feet, and to find better footing.

1. The Philosophical Imperative for a Symbiotic Design

Before a new framework for action can be constructed, the ground must be cleared. This requires an unflinching confrontation with the historical and philosophical baggage of the design discipline. For too long, design has operated under a veneer of neutrality and progress, often ignoring its deep entanglement with systems of extraction and inequality. This first part of our inquiry establishes the philosophical necessity for a symbiotic approach by dissecting this complicity, asserting design's inherent political agency, and proposing a robust ethical compass to guide its reorientation.

1.1. Confronting Design's Historical Complicity

To design responsibly, we must first grapple with *where* and *when* we are. We practice our craft not on a pristine Earth, but on a planet irrevocably altered by human activity — an epoch popularized by Paul Crutzen and Eugene Stoermer as the Anthropocene (Crutzen and Stoermer 2000). However, this term, by blaming humanity as a whole, risks masking a more uncomfortable truth. As thinkers like Andreas Malm and Jason W. Moore have argued, the defining force is not humanity in the abstract, but capitalism as a world-shaping system (Malm 2016; Moore 2016). Therefore, it is more accurate and more honest to assume we are in the Capitalocene: the Age of Capital, not just the Age of Man. This framework suggests the ecological crisis is an inherent outcome of capitalism's core logic of relentless accumulation, a logic built on a strategy of "Cheap Nature" that systematically undervalues and appropriates the unpaid work of both human and non-human life.

Historically, design has been a crucial and often willing engine for this extractive economy. Particularly since the Industrial Revolution, dominant design paradigms have overwhelmingly prioritized values like mechanistic efficiency, standardization for mass markets, and novelty for competitive advantage. This entanglement is not an accident. As argued by critics like Victor Papanek decades ago, design has been profoundly complicit in creating wasteful, harmful, and irresponsible products (Papanek 1995). It has fueled the unsustainable cycles of consumption, resource depletion, and waste generation that now threaten planetary systems. The deliberate strategy of planned obsolescence — designing products to fail or become stylistically undesirable — became a cornerstone of 20th century industrial logic, institutionalizing wastefulness for the sake of market churn (Leonard 2010).

This historical trajectory has left an enduring legacy in our built environments, consumption patterns, and ecological crises. They are the "wicked problems" — tangled, messy, and interconnected — that we now confront (Buchanan 1992). This reality places the contemporary designer at a critical crossroads: complicity or transformation? We can either continue to grease the wheels of this exploitative machine, or we can actively work to redesign the machine itself. While movements like Cradle to Cradle (McDonough and Braungart 2002) and the Circular Economy (Ellen MacArthur Foundation 2013) offer vital explorations, they often risk remaining trapped within the same industrial paradigms if they do not challenge the underlying drivers of overconsumption and inequity. A truly symbiotic perspective demands we look beyond techniques and shift what we value, moving from a narrow view of progress to a practice that actively participates in the healing and flourishing of our planet and all its inhabitants.

1.2. Design as a Political and Decolonial Act

This historical complicity forces us to confront an unavoidable truth: design is inherently, inescapably political. We may prefer to see our work as neutral or purely creative, but as Michel Foucault argued, politics is the ongoing negotiation of power relationships, and design is always in the middle of those negotiations (Foucault 1980). Every choice we make — which clients to work with, which materials to use, whose needs to prioritize, which futures to make more or less likely — is a political act that shifts power and allocates resources. Accepting a brief passively is a political act of accepting the status quo.

This political nature is deeply intertwined with design's colonial baggage. When we ask, "whose design is it anyway?", we are forced to confront the overwhelming Eurocentrism of design history and education. As scholars like Gabriel Matthey Correa have argued, many parts of the world continue to live as cultural colonies, their conceptual compass stubbornly fixed on an imposed "North" (Matthey Correa 2015). This "civilized gaze", as Sally Price termed it, implicitly devalues the diverse realities and creative contributions of others, dismissing them as peripheral or less evolved (Price 1989).

To break free from these cycles of intellectual and cultural colonialism, we must actively unpack this baggage and begin the work of decolonizing design. This means challenging the assumption that imported, universal methodologies can serve our diverse local realities. It requires constructing our own frameworks that arise authentically from our own contexts, speak to our own needs, and are woven from our unique cultural heritages. As Arturo Escobar's call for "Designs for the Pluriverse" powerfully suggests, we must strive for a world where many diverse design philosophies can flourish, each rooted in its specific cultural and ecological context (Escobar 2018). This is not just a matter of cultural respect; it is a prerequisite for creating designs that are genuinely responsive and nurturing. The ghost of Project Cybersyn in Chile serves as a potent, if tragic, reminder that groundbreaking, systemic design thinking is not confined to wealthy nations but can arise directly from urgent local needs (Beer 1973). Embracing this local identity is essential for a truly symbiotic future. *Diseñar es un acto político. ¡Siempre!*.

1.3. The Collective Genesis of the Framework

This imperative to decolonize design and build new narratives from local realities is not merely a philosophical stance; it was the methodological starting point for the creation of the Symbiotic Design Framework itself. To move beyond imported paradigms, it was essential to first ask: whose design are we actually talking about? Is it the design defined by a handful of historical figures and institutions, or the one lived and practiced by the global community of designers? The development of the SDF began by challenging the established canon. This was not a theoretical invention but a process of discovery, grounded in a decade-long inquiry. The initial doctoral research systematically investigated design through the biological lens of autopoiesis, not as an imposed metaphor, but as a way to see the discipline as a living, self-creating system (Raineri 2020).

This new way of looking was then tested against the collective reality of the discipline. A multi-stage empirical process, including a deep analysis of design's extensive literature, confronting over one hundred definitions of design and a global survey of over 360 designers, was undertaken to map the shared understanding of the practice from the ground up (Raineri 2020). This was a deliberate act of listening to the whole community, not just a few. The insights from this autopoietic view, validated by the community's own words, were then refined through an extensive series of international workshops, talks, and dialogues with practitioners and educators. This iterative validation occurred at numerous academic and industry events — from the Cumulus Rome conference and the World Design Congress London 2025 to major industry gatherings including the New European Bauhaus Festival, Valencia Design Week, Dutch Design Week, Creative Skills Week and multiple online congresses, seminars and talks mainly with Latin American Universities and events. There was a particularly deep immersion during World Design Capital (WDC)® Valencia 2022 where the opportunity to interact with designers from around the world helped to build and strengthen the framework (Raineri 2025). This process ensures the SDF is not another top-down model but a tool forged from a decolonized understanding of design itself. This new way of seeing our practice, however, demands a new way of acting. If design is a living system co-created by its community, it requires a robust ethical compass to guide its actions. This takes us to the framework's *Four Mottos*.

1.4. The Four Mottos: An Ethical Compass for Collective Flourishing

If design is to be reoriented away from its historical complicity and toward a more just and life-affirming practice, it requires more than critique; it requires a new moral compass. The Symbiotic Design Framework establishes this compass through *Four Mottos*, which are guided by a foundational commitment to ethics and the pursuit of collective flourishing (Raineri 2025).

1. Ethics: Serves as the primary, non-negotiable lens for the pursuit of collective flourishing (Eudaimonia). It is not a set of rigid rules but a dynamic commitment that holds all other considerations accountable, demanding a constant interrogation of purpose, service, and consequence. For design to establish itself as a discipline based on universal principles, the United Nations Declaration of Human Rights must be used as the foundation upon which cultural individualities must be layered. Never should one of these individualities be in opposition to the universal ones.

2. Sustainability is transformed from a technical problem of eco-efficiency into a profound ethical obligation of intergenerational and inter-species justice. It demands a systemic shift from the linear "take-make-dispose" models of the "Brown Economy," as Pavan Sukhdev termed it (UNEP 2011), toward actively regenerative systems that restore and enhance the health of social and ecological systems.

3. Social responsibility moves beyond superficial user-centredness to become an active commitment to equity, dignity, and collective liberation. It requires designers to confront systemic injustices like racism, sexism, and ableism, and to prioritize the voices and leadership of marginalized communities through genuinely participatory and co-design methodologies (Raineri 2019b).

4. Economics is wrested from the narrow logic of profit maximization and repositioned as an ethical pursuit of shared prosperity, needs fulfilment, and resilience. It champions generative models that create multiple forms of value and challenges the extractive logics of the Capitalocene by orienting economic activity toward meeting fundamental human needs, as articulated by thinkers like Manfred Max-Neef (Max-Neef 1991).

This ethical architecture, which embraces a plurality of voices from feminist, Indigenous, and decolonial thought, ensures that the pursuit of equality is always guided by a profound sense of responsibility. It transforms ethics from a perceived constraint into the very source of creative, relevant, and potentially transformative design practice.

2. The Theoretical Foundations in Systems Biology and Cybernetics

To move beyond critique and philosophy toward a new mode of practice requires a robust theoretical engine. A framework aimed at navigating complexity cannot be built on intuition; it must be grounded in a logic that can grapple with interconnectedness, emergence, and change. This part of our inquiry traces the intellectual lineage of the Symbiotic Design Framework, demonstrating how it is rooted in a long tradition of systemic thought and how it finds its core operational logic in the biological theory of autopoiesis.

2.1. Unearthing Systemic Roots

My own journey toward this framework began with a dissatisfaction with the conventional, often Western-centric, histories of design. The relentless focus on the Industrial Revolution and the Bauhaus felt incomplete, ignoring a deeper, more ancient current of systemic wisdom. I began to see that the recent interest in systems thinking was not an invention but a rediscovery of principles lived and practiced for millennia. Echoes of systemic thought are found in antiquity: from the Greek ideal of *kalokagathia* (the harmony of the good and the beautiful) to the Buddhist concept of *pratītyasamutpāda* (dependent origination), which posits that all phenomena exist only within a web of interdependent relationships.

This ancient wisdom was made manifest in profoundly systemic designs. The 9th-century temple of Borobudur in Indonesia, for instance, can be understood not merely as architecture but as a large-scale systemic design in action. Its structure is a three-dimensional mandala mapping Buddhist cosmology, guiding pilgrims through a transformative spiritual experience. Its construction required meticulous coordination and the integration of diverse skills, all orchestrated to fulfill a complex spiritual/educational purpose. Borobudur stands as a testament to a holistic worldview where every element is interdependent, challenging the notion that complex, purpose-driven design is a purely modern phenomenon.

In the mid-20th century, these intuitive understandings began to be formalized. Ludwig von Bertalanffy's General Systems Theory (GST) provided a language for understanding emergent properties in whole systems (von Bertalanffy 1968), while Norbert Wiener's Cybernetics focused on feedback loops and self-regulation. Pioneers like Buckminster Fuller, with his concept of "Spaceship Earth" (Fuller 1971), and Victor Papanek, with his fierce advocacy for social and ecological responsibility (Papanek 1995), began to apply these systemic ideas directly to the practice and ethics of design, laying the groundwork for the discipline to evolve beyond aesthetics and function toward a truly systemic engagement with the world.

2.2. Autopoiesis: The Logic of Self-production

If living beings have existed on our planet for more than 3.7 billion years, wouldn't it be interesting for design to learn something from them? Shouldn't design begin to be structured along the same lines, as a way of integrating into this sustainability model?

And here is where the most illuminating concept in this journey, autopoiesis comes to play. A theory developed by Chilean biologists Humberto Maturana and Francisco Varela to answer the fundamental question: "what is a living system?" (Maturana & Varela 1994). Their answer was a neologism, a "word without a history," derived from the Greek for "self-production." Autopoiesis defines a living system as a network of processes that continuously produces and regenerates the very components that constitute the network, thereby maintaining its identity and coherence over time. This continuous self-production is what distinguishes the living from the non-living. This is what has sustained life on our planet.

It is crucial to contrast this with allopoiesis ("other-production"), which describes systems like a factory that produce something organizationally distinct from themselves. A car factory produces cars, but it does not produce new car factories. A living cell, however, produces the components that allow it to continue existing as a living cell (Maturana and Varela 1994). This distinction is paramount: I argue that while individual design artifacts are allopoietic outputs (a chair does not produce more chairs or repair itself), the discipline of design itself operates autopoietically (a chair becomes an input for Design to self-create itself as a discipline) (Raineri 2020).

2.3. The Design Discipline as an Autopoietic Social System

Applying the logic of autopoiesis to design — a move inspired by sociologist Niklas Luhmann's application of the theory to social systems — provides a powerful lens for understanding its dynamism, resilience, and often, its resistance to change (Luhmann 1991; Raineri 2020). The discipline of design can be understood as a self-creating and self-maintaining social system that perpetuates its own existence through its internal operations. This manifests in several key ways:

- **Self-production:** Design continuously produces its own essential components. It generates its own knowledge, methods, and theories through research, practice, and critical discourse. It reproduces its practitioners through educational systems and professional enculturation. And it maintains its own discourse through journals, conferences, and publications, which weaves the fabric of its identity.
- **Organizational closure:** The system defines its own operational logic. Design itself, through its community and institutions, determines what constitutes "good" or "legitimate" design. It operates according to its own internal, self-referential criteria, which allows it to maintain a distinct identity from adjacent fields like art or engineering.
- **Structural coupling:** Despite its operational closure, design is not isolated. It is in a constant "co-evolutionary dance" with its environment. It absorbs technological innovations, responds to societal pressures, and is influenced by economic models. This process of structural coupling allows the system to adapt and remain relevant without losing its core identity.

Understanding design as an autopoietic system is not merely an academic exercise. It reveals that to change design's outputs — to make it more sustainable and just — we cannot simply impose external rules. We must intervene in its very processes of self-production, introducing new values and ethical considerations into the "genetic material" of its knowledge, its education, and its discourse.

3. The Operational Anatomy of the Symbiotic Design Framework

Having established the philosophical imperative and theoretical foundations for a new approach to design, we now turn to the practical question of its operation. A framework must be more than a theory; it must provide a tangible structure for analysis and action. This final part of this inquiry dissects the operational anatomy of the Symbiotic Design Framework, detailing the constituent components of the design process and the relational logic used to diagnose and guide their interaction.

Before detailing the components, it is essential to introduce the framework's core analytical logic: symbiosis, the logic of interdependence. Borrowing from ecology, we can classify all relationships within a design system as belonging to one of six types, which fall into two categories: sustainable relations (mutualism [+,+], commensalism [+,=], neutralism [=,=]) and unsustainable relations (parasitism [+,-], amensalism [=,-], competition [-,-]). *The Four Mottos* provide the criteria for judging whether an impact is positive, negative, or neutral. The goal of the symbiotic designer is to diagnose these relationships and actively intervene to shift them away from parasitic or competitive states and toward mutualistic ones (Raineri 2019a). The relationship, not the isolated component, is the central unit of analysis.

3.1. The Constant Influence of Time

Beyond the logic of symbiosis, the constant influence of time must be recognized not as a passive backdrop but as an active, constitutive medium within which all design activity unfolds. Time is the relentless, dynamic current that shapes, constrains, and ultimately defines the practice. The **Past** shapes present conditions through legacies, precedents, and path dependencies, offering a rich archive of lessons if we are willing to learn from the "giants on whose shoulders we stand" (Eco 2001). The **Present** is the dynamic, Heraclitean flux where all action and interaction occur. It is the only moment of agency, demanding critical engagement and a conscious distancing to truly perceive its nature, as Giorgio Agamben (2009) suggests is necessary for understanding contemporaneity. Finally, the **Future** represents the horizon of design's "projectual" nature – its inherent orientation towards envisioning and shaping what is to come (Maldonado 1972). This forward-looking stance is imbued with an ethical responsibility for long-term consequences and the fostering of pluriversal possibilities (Escobar 2018). The framework also considers how different types of events — unique, predictable, erratic, recursive, simultaneous, or sequential — unfold within this temporal flow, influencing design strategies and demanding adaptive responses.

3.2. The Anatomy of Design: Dimensions and Components

To make this relational and temporal analysis operational, the framework maps the design process across three interconnected dimensions. The **Design Core** is the autopoietic engine where the discipline's identity and knowledge are self-produced. The **Design Frontier** is the dynamic interface of structural coupling, where design negotiates with the external world of clients, manufacturers, and real-world constraints. The **Environment** is the broader ecological niche – the societal, cultural, and biophysical context in which design's outcomes operate and have its impact.

Within these dimensions, the framework identifies seven essential, interdependent components that constitute the anatomy of any design process (Raineri 2021). Each component answers a fundamental question, providing a systematic way to deconstruct and analyze a design challenge:

- **The human component** (Who?): The referential cornerstone of the framework, this component encompasses the human agents – designers, users, communities – whose agency, capabilities, and ethics drive the entire process. The **Human** component is the source of the conscious, intentional action (*heteropoiesis*) that defines design (Maturana & Varela 1994). It is where the Four Mottos are enacted and where ethical responsibility resides.
- **The commission component** (Why?): This is the emergent spark that initiates design, articulating the need, problem, or opportunity to be addressed. The **Commission** provides the initial purpose, defining the problem or opportunity that galvanizes the system into action.
- **The observations component** (Based on what?): Functioning as the cybernetic sensory apparatus, this is the process of gathering, interpreting, and learning from Design's actions and the environment to inform action. The **Observations** component provides the crucial feedback loop, grounding the process in an enacted reality and enabling the system to learn and adapt.
- **The procedures component** (How?): This is the operative engine, comprising the "designerly" methods and workflows used to translate intent into reality. The **Procedures** component provides the operational structure, the unique methods that distinguish design practice.
- **The partners component** (With whom?): This component represents the collective network of collaboration and co-creation. The **Partners** component is the medium for collaboration and co-evolution, bringing diverse knowledge and perspectives into the process.
- **The technological component** (With what?): These are the building blocks of creation, encompassing all materials, tools, systems, energy, and labour. The **Technological** component provides the material means for creation, the tangible resources that are shaped by design intent.
- **The outcomes component** (What?): This represents the tangible and intangible creations – projects, products, processes, and impacts – that result from the design process. The **Outcomes** component represents the realized outputs and their ripple effects, which in turn become part of the environment to be observed, creating a continuous cycle of making and learning.

By systematically analyzing a design challenge through the lens of these seven components and diagnosing the symbiotic nature of their relationships, the designer is equipped with a powerful tool for navigating complexity. It allows for the identification of points of extraction or harm (parasitism) and the strategic intervention needed to foster reciprocal benefit (mutualism), thereby moving the entire system toward a more resilient, just, and regenerative state.

Conclusion

The Symbiotic Design Framework is a call for a profound paradigm shift. It asks us to move beyond a conception of design as the creation of isolated objects and toward an understanding of design as the conscious and ethical stewardship of relationships within complex, living systems. By integrating a critical philosophy that confronts our discipline's complicity, a robust biological theory that illuminates its dynamic nature, and a detailed operational anatomy that enables practical intervention, the SDF offers a holistic model for a more responsible practice (Raineri 2025).

This framework is not a final answer or a rigid formula. It is a stance – a way of showing up inside living systems with our sleeves rolled up and our conscience switched on. It demands that we design as active participants, not detached spectators; that we make room for a plurality of worlds; and that we stay with the consequences of what we change. It is a commitment to solidarity, care, and the difficult, necessary work of repair. As Richard Buckminster Fuller urged, "you never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete" (Fuller 1971). The Symbiotic Design Framework is an attempt to begin building that new model, one that bends our systems away from extraction and toward reciprocity, proving that design can be a force for healing in a century that badly needs it.

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Shifting from Spectacle to Landmark: Regenerative Design Practice of the *Snowy Lilac* Cauldron Tower for the 2025 Harbin Asian Winter Games

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Abstract

Mega-event infrastructure frequently becomes a burdensome "white elephant" post-event, with prevailing sustainability efforts often criticized as greenwashing. This paper argues for a paradigm shift from this disposable, extractive model towards one centred on creating enduring, regenerative legacies. Through a single-case embedded design study, it examines the *Snowy Lilac* main cauldron tower for the 2025 Harbin Asian Winter Games, a project explicitly guided by regenerative design principles. The analysis reveals three core strategies: (1) Environmental Prioritization and Resilience Adaptation through material innovation and efficient modular construction; (2) Structure-Function Transformation via a 'plug-and-play' system that converts the ceremonial flame apparatus into a permanent light art installation; and (3) Regional Cultural Re-embedding, which integrates local symbolism to foster sustained community identity. These strategies collectively demonstrate how mega-event infrastructure can transcend its role as a temporary spectacle to become an 'eternal landmark' that contributes positively to its social and ecological context. This project offers a tangible and replicable model for future mega-events, showcasing a pathway toward a more regenerative future invested in planetary health.

Keywords: Mega-events, Olympic legacy, Olympic cauldron tower, regenerative design, sustainable architecture.

1. Introduction

Mega-events, as complex socio-engineering platforms, have long transcended the realm of athletic competition, increasingly bearing a triple-bottom-line responsibility across economic, environmental, and social dimensions (Weiler and Mohan 2010). However, despite the International Olympic Committee's (IOC) emphasis on "leading global sustainable development", a critical implementation gap persists in the construction, operation, and legacy transformation of the Olympic Games (Cain and Callan 2025). After the global spotlight fades, the monumental infrastructure built for these transient spectacles often devolves into functionally obsolete and costly "white elephants", imposing long-term economic and community burdens on host cities (Flyvbjerg and Stewart 2012). Despite the IOC's long-standing advocacy for sustainability, this chasm between grand promises and harsh realities has led academia to sharply criticize the prevailing discourse as greenwashing — a marketing tactic to cultivate a positive environmental image rather than achieving genuine environmental benefits (Glasson et al. 2024). Against this backdrop, the discourse on Olympic design urgently needs to shift from symbolic sustainability rhetoric toward a more systematic and forward-thinking regenerative transformation. Situated within this academic context, this paper selects the *Snowy Lilac* main cauldron tower for the 2025 Harbin Asian Winter Games as its case study. Guided explicitly by regenerative design principles from its inception, the project aims to explore how mega-event infrastructure can escape the fate of disposability and create an enduring cultural and ecological legacy. By employing a single-case embedded design research method, this study delves into its design practice, seeking to reveal the paradigm shift from a temporary, extractive spectacle to a sustainable, regenerative legacy, and to provide a systematic framework for the future planning of mega-event infrastructure.

2. Related Work: The Theoretical Evolution from Disposable Spectacle to Regenerative System

This section aims to systematically review the theoretical evolution of infrastructure design in mega-events, arguing for the necessity of regenerative design in addressing the legacy dilemma. By examining the post-event treatment of monumental structures and critiquing the shortcomings of mainstream sustainability discourse, it ultimately posits regenerative design as a theory for creating net-positive ecological impact, thereby establishing a theoretical foundation for the design practice of the *Snowy Lilac* cauldron tower in Harbin (China).

2.1. The Evolution of Mega-event Legacy Research

Mega-events have historically been viewed as engineering platforms; however, the ceremonial installations built for these ephemeral global spectacles face the post-event predicament of becoming "white elephants" (Patel, P. A. Bosela, et al. 2013). The cauldron tower, as a core component of this ceremonial spectacle, epitomizes this dilemma in post-event fate. As shown in Figure 1, the post-event treatment of main cauldrons has trended from direct dismantling toward preservation and relocation. Nevertheless, most designs have not fundamentally escaped their fate as temporary installations. The disassembled petal cauldron of the London Olympics, while a modular experiment, failed to achieve enduring, localized legacy value. In response to this escalating legacy problem, academic focus has shifted beyond tangible facilities, giving rise to the core legacy concept, which emphasizes that a design component cannot be treated as an isolated, time-bound work of art (Kasimati 2015).

Event Year	Location	Structure/ Installation	Design attribute	Post-Games fate/treatment
1952	Helsinki (Finland)	Cauldron Tower	Temporary installation	Dismantled/Disassembled post-Games (Olympic Cauldron Lighters)
1968	Grenoble (France) *Winter Games*	Cauldron Tower	Ceremonial structure	Relocated to Parc Paul Mistral for preservation
1976	Montreal (Canada)	Olympic Stadium	Permanent, highly specialized venue	Permanently retained, but a legacy failure due to cost overruns (Patel, P. Bosela et al., 2013)
1992	Barcelona (Spain)	Main Stadium Cauldron	Permanent, single-function	Preserved in situ
2002	Salt Lake City (USA) *Winter Games*	Cauldron Tower	Ceremonial structure	Refurbished and moved to a new park for permanent display (@theU, 2025)
2004	Athens (Greece)	Numerous Olympic venues	Highly specialized venues	Mostly abandoned and derelict (Francisco, 2025)
2012	London (United Kingdom)	Petal Cauldron Tower	Modular, highly ceremonial	Disassembled, components distributed (Staff 2012)
2016	Rio de Janeiro (Brazil)	Kinetic Sculpture Cauldron	Artwork, low-emission	Relocated to a park for permanent display

Table 1: Chronology of post-event treatment of Olympic main cauldrons.

2.2. The Limitations and Critique of Sustainability Discourse: Greenwashing in Olympic Design

The sustainability discourse was introduced into the Olympic movement in the 1990s, marked by the "temporary construction combined with post-Games functional conversion" model pioneered at the 1994 Lillehammer Winter Olympics. Subsequently, the IOC integrated environment and sustainable development into the Olympic Charter (Essex and Latuf de Oliveira Sanchez 2024). In practice, however, a significant gap exists between sustainability commitments and systemic ecological transformation. The sustainability strategies of many host cities have been criticized as greenwashing, a marketing tool to project a positive environmental image rather than achieving tangible environmental benefits (Cain and Callan 2025). Since 2012, the Olympics have been undergoing an "environmental regression", with environmental considerations not being a binding rule for the IOC (Manoli et al. 2025). Consequently, approaches like temporary construction and functional conversion remain confined to the traditional 3R principles of sustainable design (reduce, reuse, recycle), with the goal of merely mitigating harm (Kumar et al., 2025). Fundamentally, this limitation fails to alter the extractive relationship that mega-event infrastructure often has with local culture and the environment.

2.3. Regenerative Design: A Theoretical Frontier Beyond Sustainability

Regenerative design proposes a paradigm shift, aiming to create positive impact by enabling human activities to actively participate in and enhance the health of ecological and social systems. Its core principles can be summarized as 3R+: restore, renew, and replenish. Unlike sustainable design, which focuses solely on the project itself, regenerative design expands the system boundary to encompass the entire local ecosystem in which the project is situated (Living Building Challenge Basics - Living Future 2022). Its primary goal is to achieve a "net-positive" systemic contribution (Toner et al. 2023). Prominent examples include the Eden Project, which transformed a derelict clay pit into the world's largest greenhouse botanical garden (Christy 2007), and the Bullitt Centre in Seattle, which generates more electricity from its rooftop solar panels than it consumes annually (Homchick Crowe 2020). Therefore, regenerative design theory mandates that design should no longer create an isolated, eventually neglected object, but rather cultivate a living system capable of continuously empowering the local ecology and community. The Harbin cauldron tower treats the flame-lighting ceremony as a transient phase in the system's life cycle, ensuring a seamless transition to its role as a permanent cultural landmark.

3. Research Design and Methodology

3.1. Research Method: Qualitative Case Study

This study employs a single-case study method within a qualitative research framework to investigate the systematic application of regenerative design principles in mega-event infrastructure.

The case study is an empirical research method used for in-depth analysis of contemporary phenomena within their real-world context (Yin 2018). Single-case studies can be categorized as either holistic or embedded designs. A holistic design focuses on the overall characteristics and systemic logic of a case. For instance, Wilson (1996) treated the Sydney 2000 Olympics as a single unit of analysis to examine its urban vision and cultural identity narrative within the bidding context (Wilson 1996). Similarly, Boykoff and Mascarenhas (2016) used the Rio 2016 Olympics as a holistic unit to explore the operational logic of the "sustainable development" discourse in urban governance and image-making, exposing the political-economic mechanisms behind greenwashing(Boykoff and Mascarenhas 2016). An embedded design, in contrast, establishes multiple sub-units of analysis within a holistic context to reveal the multidimensional mechanisms and hierarchical structures of a complex system. For example, Searle et al. (2012) analyzed the Sydney 2000 Summer Olympics through multiple sub-units — including venue construction, ecological restoration, transportation infrastructure, tourism economy, and urban spatial renewal — to comprehensively assess the long-term impacts of the Games on urban structure, sustainability, and spatial legacy (Searle et al. 2012) .

Aligning with the objectives and analytical framework of this study, a single-case embedded design research method is adopted. Focusing on the ecological, structural, and cultural sub-units of the *Snowy Lilac* cauldron tower for the Harbin 2025 Asian Winter Games, this paper seeks to answer three core questions:

1. How are regenerative design principles embodied and operationalized in mega-event infrastructure?
2. How do design strategies achieve a systemic transformation from an event-time spectacle to a post-event legacy?
3. How does this transformation generate sustainable value mechanisms at the environmental, structural, and cultural levels?

3.2. Case Selection

The *Snowy Lilac* cauldron tower was selected as the subject of this study based on its typicality, complexity, and completeness as a regenerative design practice. The project embodies the core values of regenerative design throughout its conceptualization, implementation, and subsequent operational phases, making it a representative case with significant academic research value.

Typical application of regenerative design principles: Completed in January 2025, the *Snowy Lilac* cauldron tower is one of the first major international event infrastructures in China to be explicitly guided by regenerative design principles from its initial stages. From the outset, its design aimed to "restore ecosystem health, renew socio-cultural vitality, and replenish community development momentum", striving for a "net-positive impact" across environmental, social, and cultural dimensions. This provides a practical model for addressing the legacy problem of mega-events.

Long-term operational demand and positioning: The cauldron is located within the Harbin Ice and Snow World, the world's largest ice and snow theme park, a site characterized by high-density, year-round public flow. This unique geographical and cultural context provides the project with a clear long-term operational demand and background, thereby avoiding the common "post-event idleness" or "white elephant" dilemma at the policy and planning levels.

A fully traceable design pathway: The *Snowy Lilac* project encompasses a full life cycle, from conceptualization and schematic design to construction, post-event transformation, and long-term operation, featuring a complete and traceable data chain. As a member of the project's design team, the author had direct access to multi-source information which enabled a comprehensive reconstruction of the project's regenerative design evolutionary path.

3.3. Analytical Framework

This study's analytical framework is grounded in the core tenets of regenerative design, aiming to construct a systematic path for analyzing how the *Snowy Lilac* cauldron tower achieves a regenerative transformation from an event-time spectacle to a post-event landmark on multiple levels. As a concept that transcends traditional sustainable design, regenerative design not only focuses on mitigating negative environmental impacts but also emphasizes the restoration of ecosystem health, renewal of socio-cultural vitality, and replenishment of community development momentum through design practice (Reed et al. 2007). This paper proposes a threefold analytical framework composed of environmental, structural, and cultural dimensions to systematically examine the project's regenerative mechanisms at different levels. The analysis will proceed along the following three dimensions:

- Environmental prioritization and resilience adaptation;
- Structure-function transformation;
- Regional cultural re-embedding.

4. Case Analysis: The Regenerative Design Practice of the *Snowy Lilac* Cauldron Tower

4.1. Site Context: A New Landmark in Harbin Ice and Snow World

The *Snowy Lilac* cauldron tower for the 9th Asian Winter Games is situated within the Harbin Ice and Snow World park, adjacent to the 120 metre high Snowflake Ferris Wheel (Harbin News Net 2024) (Image 1). As one of the world's largest ice and snow theme parks, Ice and Snow World boasts extensive international influence and a stable stream of visitors, providing an excellent site condition and audience base for the cauldron's sustainable post-Games use.

For example, during its 68-day operating period, the 26th Harbin Ice and Snow World received over 3.56 million visitors, setting a new record (Xinhua English News 2025). This massive visitor flow provides a natural guarantee for the *Snowy Lilac* to transition from a functional event facility into a permanent landmark with lasting cultural impact.

Image 1: The site satellite map of the Harbin Ice and Snow World.

4.2. Strategy One: Environmental Prioritization and Resilience Adaptation

The design of the *Snowy Lilac* cauldron tower systematically addresses the practical challenges of the site environment and extreme climate, achieving a balance between visual aesthetics and structural resilience.

In terms of visual and site relationships, the tower is located on the bank of the Songhua River at a key visual node within Harbin Ice and Snow World. After comprehensive consideration of the actual conditions, the final height was set at 28.55 metres. This ensures that it forms an appropriate visual dialogue with the 120 metre Snowflake Ferris Wheel while maintaining its own slender presence as a landmark and harmonizing with the overall environment.

Regarding materials and weather resistance, to adapt to Harbin's severe winter temperatures, which can drop below -30°C, the design team integrated material science and structural engineering. 316 stainless steel, known for its excellent low-temperature toughness, was selected for key structural parts to prevent cold brittleness. The tower surface is coated with a special low-temperature fluorocarbon paint, which offers high adhesion and weather resistance against significant temperature fluctuations and freeze-thaw cycles. Expansion joints were also incorporated into the structure to allow for thermal expansion and contraction, ensuring overall stability and durability.

In terms of efficient construction and environmental impact, the tower's complex curved surface was divided into 56 independent units, adopting a lean construction model of "factory prefabrication, modular division, segmented transport, and on-site assembly" (Figure 1). This strategy moved the main construction processes into a controlled factory environment, effectively overcoming winter construction constraints. The main structure was assembled on-site in just 60 days, reducing environmental impact and the risks associated with high-altitude work.

For energy conservation and maintenance, the lighting system utilizes low-temperature-resistant LED sources and intelligent control technology, allowing for precise adjustment of lighting effects, optimizing energy consumption, and reducing long-term operational and maintenance costs.

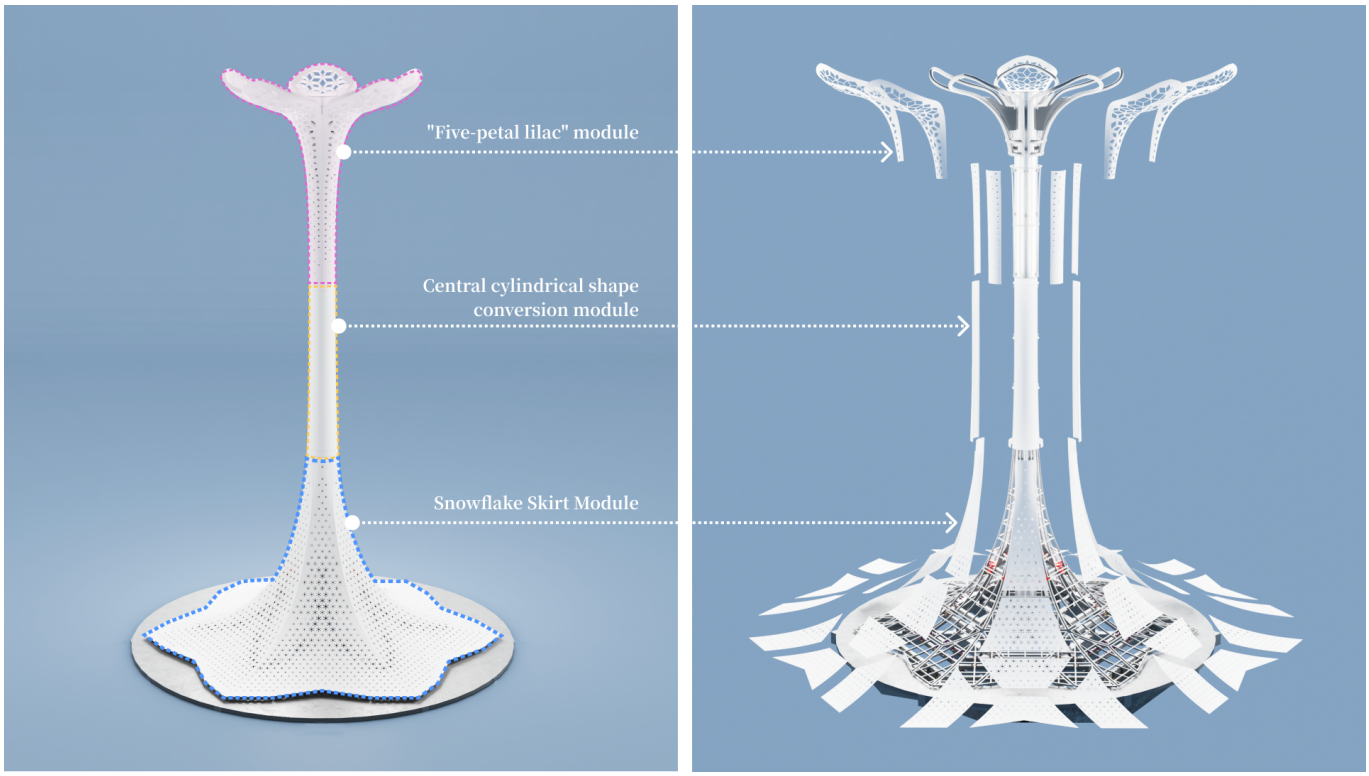

Figure 1: 56 independent modules of the Cauldron Tower façade.

4.3. Strategy Two: Structure-function Transformation

The project's key sustainability strategy is structure-function transformation, aimed at solving the single-use problem common to mega-event facilities, thereby achieving resource conservation and life cycle extension.

The core innovation of this cauldron tower lies in its plug-and-play modular combustion system design. The flame system is designed as an independent, standardized module that can be entirely removed and replaced, allowing the main structure of the tower to be permanently preserved. After the Games, the top combustion module can be swapped with a pre-designed LED dynamic light installation that conforms to the same interface standards, achieving a seamless transition from "sacred flame" to "light art" (see Image 2). This transformation utilizes the existing electrical and control wiring, converting the cauldron from a ceremonial event apparatus into a permanent visual focal point in the city's nightscape. This modular, convertible design, with its focus on the entire life cycle, demonstrates the feasibility of addressing the disposability dilemma through efficient resource utilization. It significantly extends the tower's physical and social lifespan, embodying the practical value of architectural sustainability in event facilities.

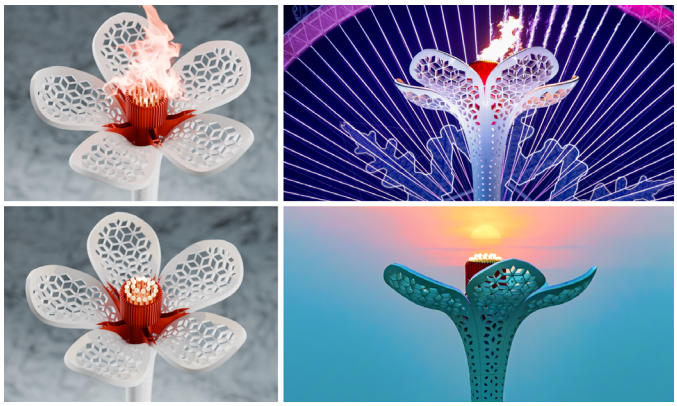

Image 2: The cauldron tower head of Snowy Lilac design drawings (left) and as-built condition (right).

4.4. Strategy Three: Regional Cultural Re-embedding

The design of the *Snowy Lilac* is a translation and revitalization of regional cultural symbols and the Olympic spirit, aimed at fostering sustained emotional resonance and cultural identity.

In the translation and revitalization of urban symbols, the design team skillfully integrated Harbin's city flower, the lilac, with the universal symbol of the snowflake. In local culture, the rare five-petaled lilac is considered a symbol of good fortune, with popular local customs such as searching for them and official photo events underscoring its cultural value (Heilongjiang Daily 2025). The snowflake is a globally recognized symbol of ice and snow culture and sports. The design organically combines these two elements, creating a form that evokes an image of concentric blooming. This activates and perpetuates the regional cultural symbol, effectively enhancing the city's cultural identity (Harbin Daily 2024).

In embedding the Olympic spirit into the daily life of the city, the post-Games replacement lighting installation artistically perpetuates the imagery of the Olympic flame through programming. At night, dynamic light effects continuously enact the flame's ignition, ascension and efflorescence, embedding the Asian Winter Games theme of *Dream of Winter, Love among Asia* into the collective cultural memory through the city's nocturnal landscape.

Ultimately, the cauldron tower successfully completes its identity transformation from an event-time symbol to an eternal landmark. With its elegant form and continuous post-Games light art display, the tower quickly became a popular gathering place and photo spot for the public (Image 3), fully demonstrating the sustained emotional resonance and cultural identification it generates as a permanent piece of public art, and underscoring its value as a new urban landmark.

Image 3: After the Games, the Snowy Lilac cauldron tower became a gathering place for the public.

5. Discussion

This study, through an in-depth analysis of the *Snowy Lilac* cauldron tower, reveals the practical pathways and profound value of regenerative design theory in the field of mega-event infrastructure. This chapter aims to create a theoretical dialogue between the findings of the case analysis and the literature review in section 2, exploring the replicability and challenges of this model, and proposing directions for future research.

5.1. The Snowy Lilac's Response to Regenerative Design Theory

The *Snowy Lilac* project effectively responds to the core critiques within mega-event legacy research and constitutes a powerful practice of regenerative design theory. Firstly, through its "structure-function transformation" strategy, the project directly challenges the single-use dilemma commonly faced by Olympic cauldrons (Patel, P. Bosela et al. 2013). Its plug-and-play modular combustion system is a deepening of the core legacy concept (Kasimati 2015); it not only pre-configures post-Games functionality but also provides the physical carrier and technical pathway for this transformation, thereby completely avoiding the fate of post-event dismantling or abandonment. Secondly, the project transcends the limitations of traditional sustainable design, which focuses merely on harm reduction (Kumar et al. 2025), and actively practices the core regenerative tenet of creating positive impact (Toner et al. 2023). Its design not only minimizes its environmental footprint through efficient construction and energy-saving operations but also, through the re-embedding of regional culture, transforms an external event symbol into a cultural catalyst that continuously inspires community identity and activates urban public space. This stands in stark contrast to the superficial greenwashing criticized by Boykoff and Mascarenhas (2016). The phenomenon of the tower becoming a popular photo spot post-Games (Image 3) indicates its successful transformation from a resource-consuming object into a living system capable of continuously generating socio-cultural capital. This is precisely the net-positive systemic contribution that regenerative design pursues.

5.2. Replicability and Challenges of the Regenerative Design Model

The systematic strategies demonstrated by the *Snowy Lilac* offer significant insights for the design of other mega-event infrastructures. Its modular design and functional pre-configuration model can be widely applied to other event facilities with strong temporary demands, such as media centres and awards plazas. By pre-designing a second life for them in fields like education, commerce, or community services, the "white elephant" problem (Flyvbjerg and Stewart 2012). can be eliminated at its source. Concurrently, its strategy of "deep regional cultural embedding" provides all host cities with an effective path to localize global events (Wilson 1996) and transform short-term investments into long-term assets. However, promoting this model also faces challenges. Firstly, regenerative design demands deep interdisciplinary collaboration from the very outset of a project, involving fields such as urban planning, architecture, structural engineering, material science, and even sociology, which places higher demands on project management. Secondly, this life-cycle-oriented design may incur higher initial design and R&D costs, requiring decision-makers to adopt a longer-term value assessment standard rather than focusing solely on short-term construction costs.

5.3. Research Limitations and Future Outlook

As a single-case study as defined by Yin (2018), the conclusions of this research have certain limitations in terms of generalizability. Although the *Snowy Lilac* project provides a highly inspiring example, the specific contexts faced by mega-event infrastructures in different cities and of different scales vary widely. Therefore, future research could expand in several directions. Firstly, comparative studies of more regenerative design cases could be conducted to distill more universally applicable design principles and models. Secondly, a long-term follow-up study of the *Snowy Lilac* project, similar to Searle's (2012) long-term impact assessment of the Sydney Olympics, could be undertaken to evaluate its social, economic, and environmental benefits over several years, providing more robust data to support its net-positive impact. Finally, future research could also explore how regenerative design concepts can be integrated with broader urban development strategies such as urban renewal and community building, thereby maximizing the catalytic role of mega-events.

6. Conclusion

In response to the pervasive "post-event abandonment" dilemma and the critique of "sustainability greenwashing" in mega-event infrastructure (Glasson et al. 2024), this study, through its case analysis of the 2025 Harbin Asian Winter Games' *Snowy Lilac* cauldron tower, demonstrates that regenerative design is an effective pathway to achieving tangible value and lasting legacy. The research finds that through three core strategies — environmental prioritization and resilience adaptation, structure-function transformation, and deep regional cultural re-embedding — the *Snowy Lilac* project successfully extends its life cycle from a brief event ceremony to the enduring daily life of the city. It is no longer an isolated, disposable structure, but a living system capable of coexisting harmoniously with the environment, resonating with urban culture, and interacting with public emotion. Through a life-cycle-oriented framework spanning the pre-event, event, and post-event phases, the project showcases the immense potential and feasibility of regenerative design in addressing the complexities of mega-events.

The value of this research lies not only in providing a new theoretical lens for examining mega-event legacy issues but, more importantly, in offering a tangible and practical paradigm for future event planners, designers, and decision-makers. The *Snowy Lilac* proves that mega-event infrastructure can transcend the ephemeral nature of a spectacle to become a meaningful eternal landmark in urban development. The replicable design model it provides will help propel the infrastructure of the Olympics and other mega-events from passively reducing harm to actively creating net benefits, making a tangible contribution to a more regenerative future invested in planetary health.

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THEME 2

Economy and Design — Innovating for Circular Economies

The integration of design within circular economy frameworks is essential for achieving a sustainable future. This theme examines how design innovation supports the shift from linear, extractive economic models to circular systems that prioritize reuse, repair and recycling.

Circular Intelligence: Design-led Frameworks for Urban Food Small-medium Businesses in a Circular Economy Transition

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Abstract

Canada's approximately 21 200 quick-service food small-and medium-sized businesses (SMBs) are cultural cornerstones of urban life yet send an estimated 550 000 tonnes of food to landfills annually. Primary user research reveals that razor-thin margins, fragmented digital tools, and inconsistent bylaws keep these enterprises locked in linear 'survival-first' routines. This study asks: How can design innovation, amplified by intelligent systems, unlock circular value for SMBs without jeopardizing profitability? Using mixed-method systems mapping, strategic-foresight workshops, and concept testing, we identify three design leverage points: (1) shared circular production hubs that reduce financial barriers to adopting reuse practices, (2) Circular-Intelligence Systems (CIS) that forecast demand and visualize waste streams in real time, and (3) tokenized community credits that monetize low-waste behaviours. A backcasting roadmap to 2035 aligns these interventions with policy incentives and SMB capability-building. Findings show strong adoption intent and cost-neutral potential within the first operational year, suggesting that modest early wins can compound into regenerative business models. The paper positions designers as economic catalysts and offers a transferable playbook for other resource-intensive urban sectors.

Keywords: Circular economy, design innovation, intelligent systems, resource efficiency, service design, small-and-medium-sized businesses, strategic foresight, waste minimization.

1. Introduction

In the intricate metabolism of modern cities, small independent food businesses serve as vital cultural and economic arteries. Local cafes, family-run takeout spots, and neighbourhood bistros are engines of urban vitality, generating jobs, preserving culinary traditions, and creating the distinctive character that makes communities thrive. In Canada, the quick-service restaurant sector represents a significant economic force, with approximately 21 200 small to medium-sized businesses (SMBs) contributing billions to local economies annually. Their cultural significance is equally profound, particularly in major Canadian cities where these businesses are often run by immigrant entrepreneurs and families, weaving diverse culinary traditions into the urban fabric.

Yet this vibrancy comes with an environmental cost. Canada's quick-service food SMBs send an estimated 550 000 tonnes of food waste to landfills annually (Environment and Climate Change Canada 2023), a figure that represents more than discarded resources. It signals a systemic challenge rooted in a deeply entrenched linear economic model of 'take, make, waste' that is becoming increasingly untenable in the face of the global climate emergency. Whilst these businesses remain cornerstones of urban economic growth and cultural identity, their environmental footprint highlights a critical and often-overlooked frontier for sustainable intervention.

The circular economy (CE) offers a powerful framework for redesigning this system, moving from extraction and disposal to regeneration and restoration. Yet for resource-constrained food SMBs, the path to circularity is fraught with systemic barriers. Our primary research reveals that razor-thin profit margins (typically 3-5%) lock these businesses into a 'survival-first' operational mode, where long-term environmental goals are necessarily subordinated to immediate financial viability. This precarious position is compounded by fragmented digital tools ill-suited for small-scale operations and inconsistent municipal regulations that can stifle circular innovation. For a sector largely composed of immigrant entrepreneurs and family-run businesses, these barriers are particularly acute. Consequently, these culturally and economically significant establishments remain trapped in linear routines despite growing environmental urgency.

We had begun to address this challenge through alternative business models. The Food-as-a-Service (FaaS) framework (adapted from Tse, 2024 MRP), for instance, has demonstrated the theoretical viability of circular approaches for urban food SMBs. Whilst such frameworks establish the strategic logic of what needs to change and why it can work, a critical question remains underexplored: How does design orchestrate this transformation in practice? What specific design mechanisms translate circular principles into economically viable operations for businesses operating on thin margins?

This paper examines 'circular intelligence' as both a conceptual framework and a design praxis for addressing this gap. We argue that the connection between circular economy principles and economic viability must be deliberately designed and orchestrated. Circular Intelligence represents the design work of configuring socio-technical systems where materials, data, and value flow in ways that make sustainable practices the most profitable choice. It is not merely the application of smart technology to waste management, but a holistic approach to designing the economic, informational, and behavioural conditions under which circularity becomes the rational default for food businesses.

Through three specific design interventions for the restaurant and food service sector (shared production hubs, an AI-powered circular intelligence system, and tokenized community credits), we reveal how designers function as economic orchestrators, architecting conditions under which circularity becomes economically inevitable rather than aspirational. These interventions, validated through concept testing with restaurant owner-operators, demonstrate how design can make circular practices profitable for small food businesses.

This study asks: How does design orchestrate the connection between circular economy principles and economic viability for urban food SMBs? We present the Circular Intelligence framework as both a theoretical contribution and a practical blueprint, with insights transferable to other resource-intensive urban sectors dominated by small businesses.

2. Literature Review

2.1. Circular Economy and Design Innovation

The circular economy reframes production and consumption as continuous loops of value regeneration rather than linear throughput (Ellen MacArthur Foundation 2019; Stahel 2016). Whilst early CE scholarship emphasized material cycling and technical metabolism, design research has expanded this focus to include organizational, behavioural, and economic dimensions. Bocken et al. (2016) identified sustainable business model archetypes showing how design can integrate product, service, and system innovation. Manzini (2015) advanced design for social innovation, demonstrating how communities co-create solutions that transform everyday practices rather than merely substitute materials.

This paper extends this trajectory by positioning design not only as the visible interface of circular practices but as the architect of economic value flows within circular systems. We argue that circularity requires designing the conditions under which sustainable practices become financially rational, particularly for resource-constrained actors.

2.2. SMBs and Systemic Barriers to Circularity

Small and medium-sized businesses face distinct barriers to circular adoption compared to large corporations. Empirical studies identify prohibitive capital costs, fragmented policy environments, limited digital capacity, and survival-focused decision cycles as primary obstacles (Geissdoerfer et al. 2017; Rizos et al. 2016). Unlike large firms that can absorb experimentation costs and leverage economies of scale, SMBs operate on thin margins where circular infrastructure investments appear financially untenable.

The food service sector exemplifies these challenges acutely. High waste generation coincides with minimal operational slack, creating what we term a "financial survival loop" where immediate cost pressures prevent long-term sustainability investments. Recent work on service-based business models like Food-as-a-Service demonstrates theoretical pathways for circular SMB operations (Tse 2024), yet questions remain about the specific design mechanisms that translate theory into economically viable practice.

2.3 Intelligent Systems and Value Creation in Circular Economies

Digital technologies (artificial intelligence, Internet of Things, blockchain) are increasingly recognized as enablers of circular transitions (Cramer 2020; Bag et al. 2021). These systems provide real-time visibility of material flows, predictive analytics for resource optimization, and verification mechanisms for circular performance. However, most intelligent systems are designed for large enterprises with dedicated data infrastructure and IT capacity.

For SMBs, accessible and contextually appropriate intelligent systems remain scarce. Moreover, existing literature focuses primarily on technology deployment rather than the design work required to translate data into actionable economic value. This gap reveals a need for frameworks that position intelligence not merely as data capture but as orchestrated value creation, transforming waste first into information, then into operational and financial benefits.

2.4 Strategic Foresight and Transition Design

Strategic foresight methodologies provide tools for navigating complex, uncertain futures. Dator's (2009) Four Futures framework and backcasting approaches (Robinson 1990) enable designers to explore multiple scenarios and work backward from desired futures to identify present actions. Recent design scholarship positions foresight as essential for systemic transitions, where interventions must be robust across multiple possible futures rather than optimized for single predicted outcomes (Candy and Kornet 2019).

Transition design extends this thinking, positioning designers as facilitators of large-scale socio-technical change rather than creators of discrete artefacts (Irwin 2015; Kossoff et al. 2015). This emerging paradigm argues that addressing wicked problems like circular economy transitions requires designers to operate across multiple scales, from individual interactions to system architectures to long-term transformation pathways.

2.5 Positioning Circular Intelligence

Within this landscape, circular intelligence emerges as a design-led framework integrating these dimensions: the economic realities facing SMBs, the enabling potential of intelligent systems, and the long-term perspective of strategic foresight. We define Circular Intelligence as a dynamic socio-technical system that transforms waste into information, and then into economic value, through the designed orchestration of physical infrastructure, digital platforms, and economic incentives.

This framework contributes to circular economy discourse by demonstrating how design creates the conditions for circularity to become economically inevitable rather than aspirational, particularly for resource-constrained actors previously excluded from circular transitions. It positions designers as economic architects capable of reconfiguring value flows and incentive structures, expanding design's agency from artefact creation to system transformation.

3. Research Approach and Methods

3.1. Research Design

Addressing the circular transition challenge for urban food SMBs required a methodology capable of moving beyond analysis to actively generate and validate design interventions. We adopted a design-led, mixed-methods approach integrating systems thinking, strategic foresight, and participatory prototyping. This holistic process enabled us to diagnose systemic barriers, envision alternative futures, and translate insights into testable design proposals (see Figure 1).

3.2. Data Collection

The research combined multiple qualitative methods:

Systems mapping: we employed causal loop diagramming to visualize the interconnected web of material flows, economic pressures, actor relationships, and policy constraints defining the quick-service food ecosystem. This macro-level analysis identified critical feedback loops, particularly what we term the "Financial Survival Loop" and "Technology and Knowledge Loop", that perpetuate linear behaviours despite environmental awareness.

User studies: semi-structured interviews were conducted with 12 independent restaurant operators across Toronto and Calgary, representing diverse cuisine types and business models such as dine-in, takeout-focused, food trucks. Interview protocols explored daily operational realities, decision-making processes regarding purchasing and waste, experiences with existing digital tools, and attitudes towards sustainability. Sessions lasted 45-90 minutes and were conducted on-site to enable contextual observation of workflows, equipment, and spatial constraints.

Strategic foresight workshops: we applied Dator's (2009) Four Futures framework (Growth, Collapse, Discipline, and Transformation) to develop plausible scenarios for the urban food sector in 2035. These scenarios explored trajectories of policy evolution, technology adoption, consumer behaviour shifts, and climate impacts. Participatory workshops with business owners and sustainability experts used these scenarios as provocations to stress-test emerging design concepts across multiple possible futures.

Speculative concept test: core intervention concepts were developed into boundary objects (service blueprints, interface wireframes, and business model canvases) designed to facilitate stakeholder conversation whilst making abstract system concepts tangible. These prototypes deliberately remained at conceptual fidelity to encourage critique and co-creation rather than premature commitment to specific technical implementations.

3.3. Data Analysis

Interview transcripts were analyzed through iterative coding, producing three major clusters: economic resilience pressures, operational convenience requirements, and community participation motivations. These themes directly informed the iteration of the systems map, revealing how macro-level economic structures manifest in individual decision-making moments. The analysis confirmed that circular transitions fail not due to lack of awareness or values, but because systemic structures make linear choices the only economically rational option for businesses operating on 3-5% margins.

Foresight scenarios were analyzed for patterns across futures in 2035, identifying interventions robust enough to create value in growth scenarios (market-driven adoption), collapse scenarios (resource scarcity), discipline scenarios (regulatory mandates), and transformation scenarios (fundamental system reimagining). This cross-scenario validation ensured proposed designs were adaptable rather than optimized for single predicted outcomes.

3.4. Concept Validation

Speculative prototypes underwent scenario-based evaluation with the 12 restaurant operators who participated in initial interviews. Participants rated interventions for perceived usability (ease of adoption given current capabilities), desirability (alignment with operational needs and values), and financial viability (realistic path to cost neutrality or profitability). Evaluation sessions used structured protocols capturing both quantitative ratings and qualitative feedback on specific features, concerns, and suggested modifications. This validation process was critical for distinguishing between conceptually appealing interventions and those grounded in operational realities of small food businesses.

4. Findings

4.1. Systemic Barriers

Systems mapping and user research revealed four interconnected barriers that reinforce linear patterns in urban food SMBs:

Financial inertia: high upfront equipment costs prevent investment in circular infrastructure. Industrial composters, commercial sanitation systems for reusable containers, and anaerobic digesters represent insurmountable capital barriers for businesses operating on 3-5% profit margins.

Fragmented governance: municipal bylaws vary significantly across jurisdictions, creating inconsistent compliance landscapes. Reusable container programmes face varying interpretations of health codes. Waste diversion mandates differ in enforcement and measurement. Permitting for on-site composting varies by neighbourhood. This fragmentation increases the cognitive and administrative burden on owner-operators already stretched thin, making compliance-by-inaction the path of least resistance.

Digital disconnection: point-of-sale systems, inventory management tools, and supplier platforms operate as isolated silos, obstructing waste data visibility. Most restaurants use basic POS systems focused on transactions, not waste tracking. Inventory is managed through mental calculation or paper logs. Food cost analysis occurs monthly at best, too infrequent for operational adjustments.

Behavioural inertia: Staff routines prioritize speed and convenience over sustainability in high-pressure service environments. During rush periods, disposal bin proximity matters more than sorting accuracy. Standardized ordering habits persist regardless of actual demand variation. Training new staff on waste procedures competes with teaching food safety and customer service.

These constraints reinforce what our systems mapping identified as a 'financial survival loop' (see Figure 2): cost pressures lead to short-term procurement decisions and minimal investment in efficiency tools, which perpetuate waste and lost resource value, which further squeeze already thin margins, reinforcing short-term thinking. Breaking this loop requires interventions that address multiple barriers simultaneously rather than optimizing within the existing system structure.

4.2. Design Leverage Points: Three Modes of Circular Value Creation

Analysis of the systemic barriers revealed that breaking the financial survival loop requires design interventions operating simultaneously across three domains: information infrastructure that makes invisible flows actionable, access infrastructure that democratizes circular technology, and incentive infrastructure that aligns economic rationality with environmental outcomes (see Figure 3). Each represents a distinct mode through which design orchestrates the transformation of waste into information, and information into economic value.

1. Information Infrastructure: Design as Intelligence Translator

The first leverage point addresses the information asymmetry and cognitive overload barriers through what we term information infrastructure, systems that capture waste as data and translate complexity into actionable intelligence. Design's role here extends beyond creating better dashboards to fundamentally reconceptualizing how intelligence becomes accessible to resource-constrained operators.

The proposed digital platform demonstrates this through three design strategies. First, effortless capture: using automated sensors to quantify waste without adding labour burden, which recognizes that data collection competes with service delivery in high-pressure environments. Second, contextual translation: converting raw data into specific recommendations rather than requiring operators to interpret analytics. Third, network coordination: creating marketplace connections that transform individual surplus into collective resources through automated matching.

The critical design insight is that intelligence for SMBs requires translation. Sophisticated analytics remain inaccessible if they demand interpretation time or technical literacy that small operators lack. Design mediates between computational capability and human decision-making contexts, making intelligence actionable within existing workflows. Validation confirmed this: 83% adoption intent centred on how the system "saves time instead of adding work". Participants valued intelligence that required minimal cognitive load, not maximum data granularity.

This reveals design's role as democratizer of intelligence, creating parity between resource-rich and resource-constrained actors by restructuring how analytical capability is accessed and applied.

2. Access Infrastructure: Design as Economic Restructuring

The second leverage point addresses capital barriers through access infrastructure, shared physical systems that fundamentally restructure the economics of circular participation. Design operates here at the level of business model innovation and cooperative governance.

The proposed shared production hubs demonstrate design reconfiguring economic relationships through three mechanisms. First, cost structure transformation: converting prohibitive capital expenditure into manageable operational fees through collective ownership models. Second, collective economies of scale: enabling small operators to achieve purchasing power, processing efficiency, and technology access previously exclusive to large corporations. Third, network value creation: designing hubs as community nodes where peer learning, resource exchange, and social capital accumulation amplify purely transactional benefits.

The critical design insight is that accessibility requires economic restructuring, not just equipment provision. Simply offering composters or sanitation systems at reduced cost maintains the capital barrier logic, as businesses must still deploy upfront investment. Design's intervention operates at a deeper level: reconfiguring from individual ownership to cooperative access, from capital to operational expense models, from competition to mutualization.

Validation revealed this transformation's power: participants described the model as 'changing the whole maths' of circular viability. The economic restructuring makes circularity not just more affordable, but fundamentally rational within SMB financial logic.
This reveals design's capacity as architect of economic alternatives, creating new structures of access and ownership that redistribute opportunity.

3. Incentive Infrastructure: Design as Temporal Bridge

The third leverage point addresses behavioural inertia and temporal misalignment through incentive infrastructure, systems that make future environmental benefits tangible as immediate economic value. Design operates here as behavioural economist, structuring how value is perceived and experienced across time.

The proposed tokenized credit system demonstrates design bridging temporal gaps through three strategies. First, immediate value recognition: automatically generating tradeable credits for verified circular actions, providing instant purchasing power rather than distant payoffs. Second, network value amplification: designing credits to increase in utility as more businesses participate, creating positive adoption spirals where early joiners benefit from later growth. Third, local value circulation: structuring credits as medium of exchange within the ecosystem rather than points redeemable from external providers, keeping economic value circulating locally.

The critical design insight is that incentive alignment requires temporal translation, not just financial rewards. Cash incentives still involve delayed gratification: applying for reimbursement, waiting for approval, receiving payment weeks later. Design's intervention operates on perception and immediacy: restructuring how value flows so circular actions generate spendable currency in real-time, making tomorrow's ingredient purchase a present-moment reward for today's waste diversion.

Validation revealed this immediacy as essential: participants' skepticism transformed to enthusiasm upon understanding network effects. The behavioural shift occurs not through education about environmental benefits, but through economic redesign making sustainable actions immediately self-interested.

This reveals design's role as orchestrator of incentive structures, capable of reconfiguring how actors experience and respond to value across time horizons.

These three leverage points function synergistically: information infrastructure provides the sensing and verification enabling the other two; access infrastructure provides the physical capacity making circular actions feasible; incentive infrastructure provides the economic motivation sustaining participation. Their integration creates self-reinforcing dynamics where increased participation improves data quality, increases hub efficiency, and amplifies credit utility, strengthening the others.

This integrated framework reveals design's expanded agency in circular transitions: not creating better products or services but orchestrating the socio-technical conditions under which circularity becomes economically inevitable. Design operates simultaneously as intelligence translator, economic architect, and incentive orchestrator, requiring capabilities far beyond traditional design practice but essential for addressing systemic sustainability challenges.

4.3. Concept Testing and Validation

Twelve restaurant owner-operators participated in scenario-based evaluations of speculative prototypes representing the three interventions. Participants reviewed service blueprints and interface wireframes, then rated concepts across three dimensions and provided qualitative feedback.

Adoption intent: 83% expressed willingness to adopt the Circular Intelligence System if integrated with their existing service flow, with demand forecasting identified as the "killer feature" most likely to drive adoption. Shared hub access received strong interest (73%), with container washing and collective purchasing most valued. Tokenized credits showed moderate initial interest (58%), with skepticism focused on whether credits would be widely accepted enough to have real utility (see Figure 2).

Key design insights: Validation revealed several critical design requirements. Integration with existing POS systems is necessary, as participants will not adopt standalone tools requiring duplicate data entry. Mobile-first design is essential, as owner-operators manage operations from mobile devices.

These validation signals indicate that the Circular Intelligence framework addresses real operational pain points, with particular strength in the economic value proposition. The framework succeeds not by asking restaurants to sacrifice for sustainability, but by making circular practices the most profitable operational choice.

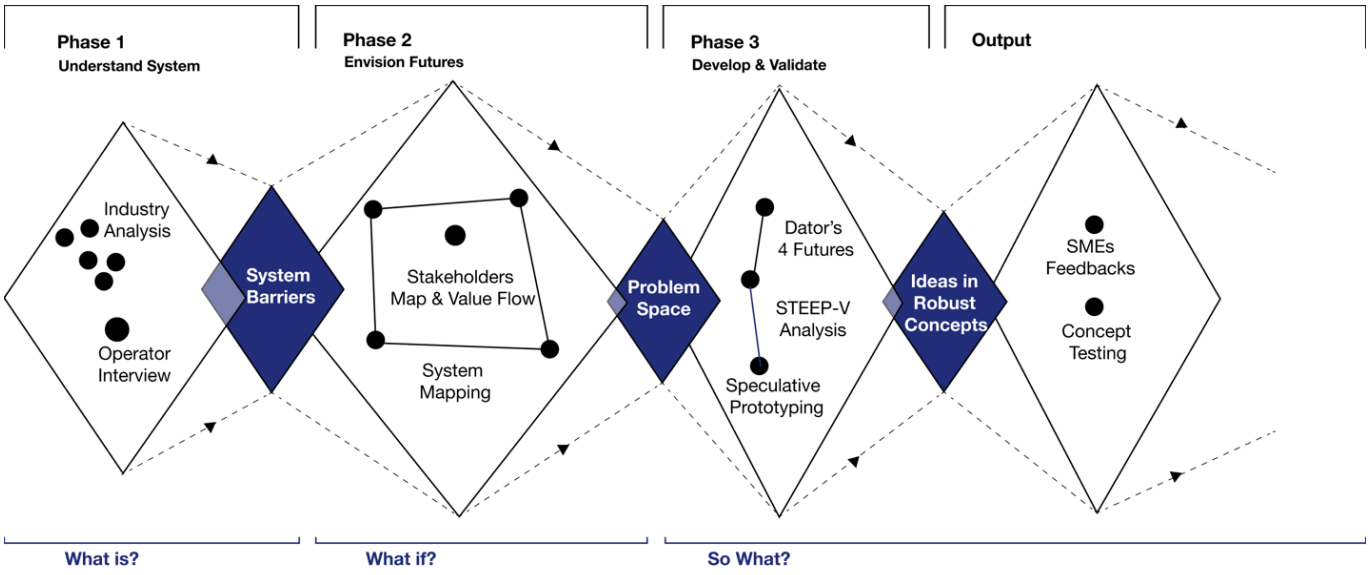

Figure 1: Design research methodology: three-phase process from diagnosis to validation.

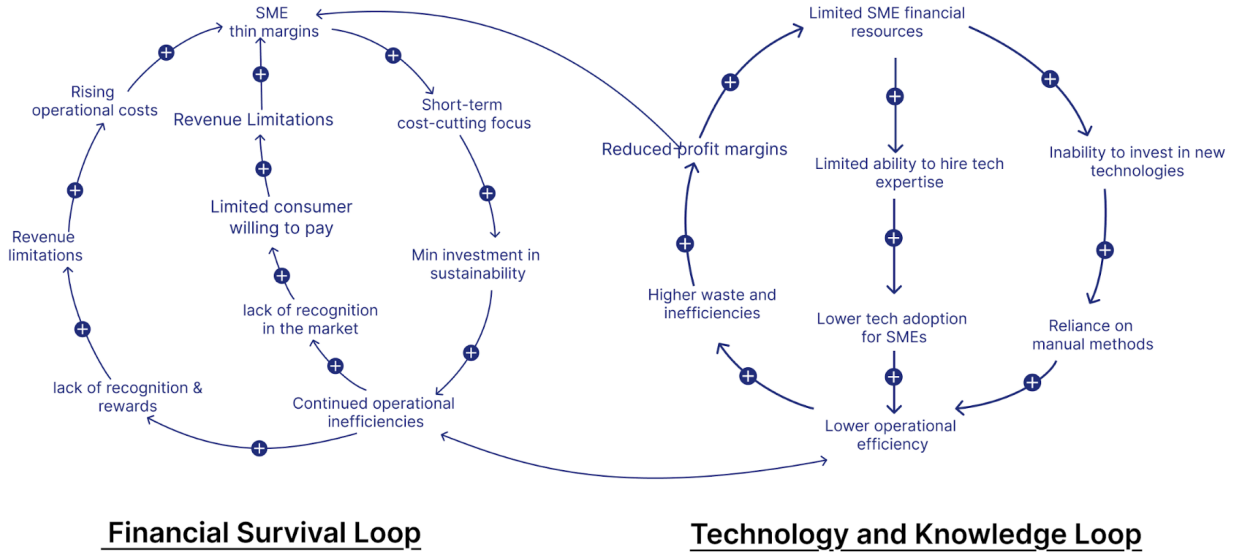

Figure 2: Interconnected systemic barriers creating reinforcing loops that trap food SMBs in linear patterns. The financial survival loop and technology and knowledge loop share critical nodes.

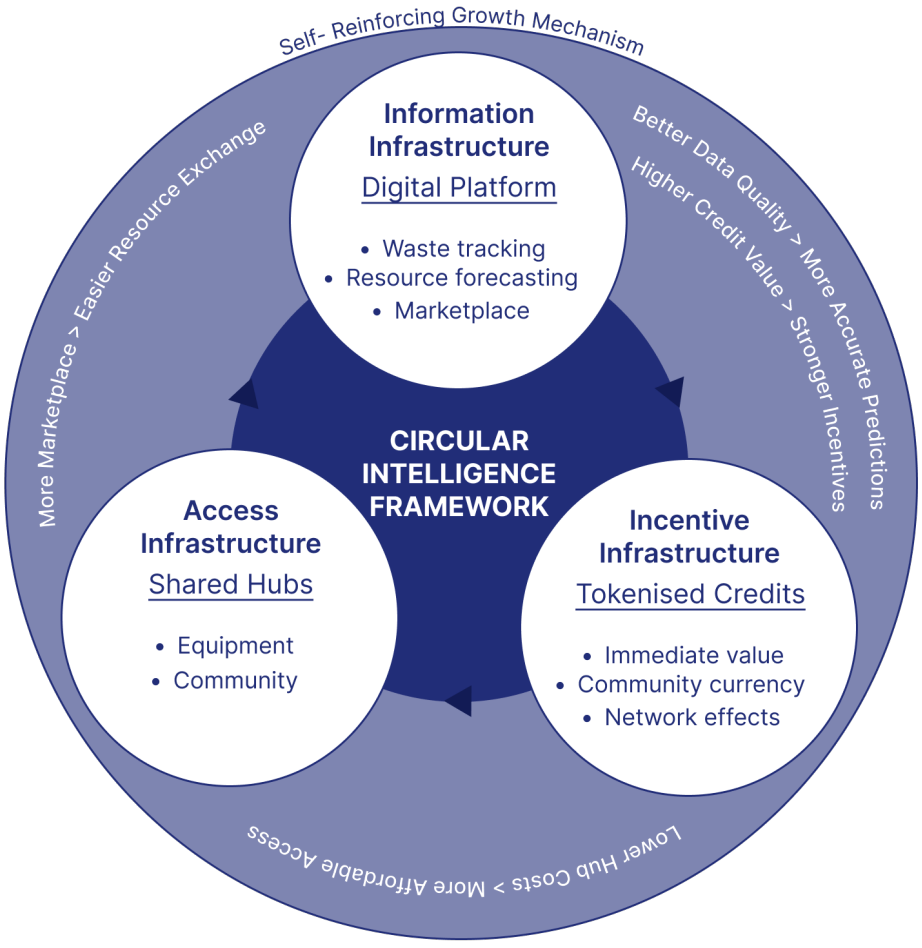

Figure 3: The Circular Intelligence Framework. Three design leverage points (information, access, and incentive infrastructure) create self-reinforcing value loops where waste becomes information, information enables action, and economic incentives drive participation, strengthening with each cycle through network effects.

5. Discussion

The findings in Section 4 demonstrate that circular transitions for urban food SMBs are achievable when design orchestrates the transformation of waste into information, and information into economic value. This section discusses broader implications for conceptualizing circular intelligence, understanding design's evolving role, and recognizing transferability of this value-creation logic across sectors.

5.1. Reframing Circularity as an Intelligent System

Traditional circular economy approaches focus on material cycles that involve designing for disassembly and optimizing reverse logistics. Our findings reveal a critical additional dimension: circularity as an adaptive intelligent system.

Circular intelligence operates through three interconnected processes: Sensing (data capture through IoT sensors, waste tracking, marketplace transactions), Learning (AI pattern recognition identifying waste patterns and optimization opportunities), and Responding (design interventions translating insights into actionable recommendations and credit generation). Through this lens, waste becomes information, fuel for systemic learning that continuously optimizes future behaviour.

This reframing positions intelligence not as a feature added through technology, but as an emergent property of designed socio-technical relationships. For instance, the restaurant owner receiving a notification to reduce tomorrow's tomato order experiences intelligence emerging from the orchestrated interaction of sensors, algorithms, economic incentives and human decision-making. Intelligence resides in the configuration of relationships, not in any single component.

This builds directly on our empirical findings that isolated interventions proved insufficient during concept testing. Participants emphasized that value emerged from integration: the platform becomes valuable because it connects to the shared hub and generates spendable credits; hubs become viable because the platform coordinates usage and verifies actions; credits become motivating because they are earned through platform-enabled, hub-supported actions. The system learns and adapts through these feedback loops, becoming more intelligent as data accumulates, networks expand, and patterns sharpen.

5.2. Design as Economic Architect

Our systems mapping showed urban food SMBs facing interconnected barriers across financial, regulatory, informational, and behavioural domains. Addressing these required design practice extending beyond aesthetics or user experience towards strategic orchestration of economic systems.

In developing the three validated interventions, designers functioned as economic catalysts to mediate between policy ambitions, technological possibilities, and user pragmatics. The framework exemplifies how design synthesizes data intelligence and empathy into actionable economic architecture.

This represents a fundamental expansion of design agency. Traditional design creates value by making things more desirable, usable, or efficient. Systemic design creates value by reconfiguring economic relationships and incentive structures. Our findings showed designers creating new revenue streams, transforming cost structures, and designing market mechanisms. Each represents design operating at the level of economic logic, not just artefact creation.

The validation findings underscore this shift: participants valued interventions not for interface elegance but for economic transformation, the ability to reduce waste and achieve cost neutrality within year one, and make circular practices more profitable than linear alternatives. Design's agency lies in architecting these economic outcomes.

Moreover, scaling the Circular Intelligence framework requires coordinated policy support. Information infrastructure needs municipal open-data mandates and innovation grants for digital tools. Access infrastructure requires subsidized facility leases, zoning allowances for urban eco-hubs, and public-private co-financing. Incentive infrastructure demands circular bylaws linking verified actions to credits, integrated with carbon accounting. Implementation requires institutionalizing feedback between SMBs and regulators through design-led advisory panels, demonstrating how design orchestrates not only technical systems but multi-stakeholder coordination for transformation (see Table 1).

5.3. How the System Becomes Self-improving

Section 4.2 demonstrated how three interventions create synergistic effects through integration. The deeper implication: circular intelligence functions through designed socio-technical feedback loops that become self-reinforcing over time.

The framework creates a participatory circular ecosystem where restaurants, consumers, municipalities, and technology providers co-create circular value. Here is how one business action triggers a continuous improvement cycle:

The physical layer: a restaurant diverts waste to the hub. Sensors automatically capture the quantity and type.

The intelligence layer: the platform verifies the action, generates credits for the restaurant, and logs the data. Over time, these data patterns enable AI to improve demand forecasting for all network participants.

The economic layer: the restaurant owner redeems earned credits for tomorrow's ingredient purchases. This transaction creates more data, further refining the system's predictions.

The reinforcement effect: as forecasts improve, all restaurants waste less. Less waste means lower hub operating costs and higher credit purchasing power, making participation increasingly attractive to new businesses.

This cycle repeats, with each iteration making the system more intelligent, more valuable, and more resilient. Behavioural incentives feed new datasets into the system to refine recommendations, improving outcomes, strengthening trust, and motivating continued participation. This is intelligence emerging through designed feedback. The system becomes smarter through the orchestrated interaction of human behaviour, incentives, technological sensing, and collective learning.

This demonstrates service design moving from micro-interaction optimization to macro-system governance. Within sustainable urbanism, this represents cities not as fixed infrastructure but as adaptive, learning systems where design configures feedback loops through which collective behaviour evolves towards regenerative patterns.

6. Conclusion

This research introduced Circular Intelligence as a design-led framework addressing how to enable circular transitions for small businesses operating under severe resource constraints. Through systems mapping, user studies, strategic foresight, and concept validation with urban food SMBs in Canada, we demonstrated that circular transitions fail not from lack of awareness but because economic systems structurally favour linear practices. Breaking this pattern requires design transforming waste into information, and information into immediate economic value.

6.1. Key Contributions

A conceptual framework for circular intelligence: we define circular intelligence as a dynamic socio-technical system transforming waste into information through sensing and learning, then transforming information into economic value through designed orchestration of physical infrastructure and digital platforms. This transformation positions circularity as orchestrated value creation and reveals design's role in architecting economic conditions where sustainable practices become most profitable.

Three validated design leverage points: we developed and validated shared production hubs, an AI-powered circular intelligence system, and tokenized community credits to demonstrate how this creates self-reinforcing circular systems. Concept testing revealed 83% adoption intent, estimated 20-30% waste reduction, and confidence in achieving cost neutrality within year one.

Design as economic architecture: we demonstrated that systemic circular economy challenges require design practice evolving from artefact creation towards economic orchestration. Designers function as catalysts mediating between policy ambitions, technological possibilities, and business pragmatics, capable of reconfiguring value flows and incentive structures at the system scale.

6.2. Future Research

Critical next steps include prototyping the circular intelligence system through municipal pilots, quantifying actual waste reduction and cost savings over extended periods, and exploring interoperability standards for SMB data exchange. Longitudinal studies should examine whether behavioural changes persist as incentives mature and whether adoption intent translates to sustained engagement. Research should investigate governance challenges of multi-stakeholder ecosystems: conflict resolution, equitable value distribution, and power dynamics as networks scale.

The broader research agenda involves understanding circular intelligence as urban infrastructure. Successful systems generate valuable data for municipal planning, with waste flows informing collection logistics and demand patterns guiding economic development. How should such data be governed as public good whilst protecting commercial interests? What standards enable interoperability between sectors?

6.3. Concluding Reflection

The circular economy represents a defining challenge of our era, yet implementation has remained frustratingly aspirational, particularly for thousands of small businesses constituting urban economic life. This research demonstrates the challenge is not technical or behavioural but fundamentally economic and systemic, and therefore addressable through design that orchestrates economic transformation.

When waste becomes information and information becomes value, circularity shifts from ethical sacrifice to economic opportunity. When shared infrastructure democratizes access to essential technology, capital barriers no longer determine who can participate. When immediate incentives align with long-term outcomes, the rational choice becomes the regenerative choice. This is the promise of circular intelligence: not mandating circularity from above or hoping it emerges spontaneously, but designing the conditions under which it becomes inevitable.

Whilst this research focuses on urban food SMBs as a starting point, the Circular Intelligence framework is designed for broader application. The three-pillar logic of information infrastructure, access infrastructure, and incentive infrastructure addresses universal barriers facing resource-constrained small businesses across sectors. Future work should test this framework's adaptability to other urban industries where SMBs dominate, examining how the waste-to-information-to-value transformation operates across different material flows and regulatory contexts.

For small food businesses, this means sustainability and profitability finally converge. For designers, it means expanding agency to shape not just artefacts but economic futures. For cities, it means evolution towards regenerative metabolism where intelligence flows as continuously as materials. The transformation is achievable, but only if we recognize it as a design problem and bring design's orchestrative capabilities to bear on the architecture of value itself.

Design Leverage Point	Primary Objective	Policy/Regulatory Mechanism	Responsible Actor(s)	Expected Outcome (2035)
Circular-Intelligence System (CIS)	Data visibility & accountability for waste reduction.	Municipal open-data mandate for food-waste reporting ; Tax credit for verified reductions ; Innovation grants for digital circularity tools.	City Sustainability Offices; Tech Start-ups; Restaurant Associations.	Real-time circular-performance data informing municipal policy and incentive design.
Shared Circular Infrastructure (Hubs)	Democratize access to circular equipment and processing.	Subsidized shared-facility leases; Zoning allowances for urban eco-hubs; Public-private co-financing schemes.	Municipal Economic Development Units; Co-ops; Local Business Improvement Areas (BIAs).	Lower capital barriers and 20–30 % waste reduction per cluster by 2035.
Tokenized Community Credits	Align short-term profit with long-term environmental goals.	Circular Incentive Bylaw linking verified actions to redeemable credits; Integration with provincial carbon accounting.	Municipal Treasury; FinTech Partners; Citizen Groups.	Behavioural shift toward reuse and local participation in circular markets.
Policy Co-creation and Governance Mechanisms	Institutionalize feedback loops between SMBs and regulators.	Design-led advisory panels; Participatory budgeting for circular initiatives.	City Councils; Design Facilitators; SME Networks.	Adaptive policy environment responding to real-time system data.

Table 1: Mapping of Design Leverage Points to Policy Instruments.

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The Conscious Choice Designing a Universal Labeling System to Solve Fashion's Crisis

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Abstract

The global fashion industry faces an urgent transparency crisis driven by overproduction, misleading sustainability claims, and fragmented communication of material impact. This paper proposes *The Conscious Choice*, a universal labeling system designed to standardize how environmental and ethical data are conveyed to consumers at the point of purchase. Grounded in qualitative and quantitative research, including interviews with fashion and communication designers and a survey of seventy-five participants, the project integrates insights from sustainable design, circular economy principles, and digital innovation. It demonstrates how visual communication and UX design can make supply-chain data more understandable, fostering accountability across brands. The labeling system employs a layered information hierarchy using colour, iconography, and QR-enabled traceability to reveal verified metrics such as water usage, material sourcing, and labour conditions. By combining design thinking with policy-aligned frameworks such as the EU Digital Product Passport, *The Conscious Choice* advocates for a transparent and informed fashion ecosystem where consumers participate consciously in sustainability transitions.

Keywords: Circular economy, communication design, labeling system, sustainable fashion, transparency, UX design.

Image 1: Hero image of *The Conscious Choice*, a universal labeling system for fashion transparency and sustainability communication. Credit: Vicky Tsiachri

1. Introduction

The fashion industry, one of the world's largest economic sectors, is simultaneously among its most environmentally destructive. Each year, more than 92 million tonnes of textile waste are produced globally, while the use of synthetic fibres and hazardous dyes contributes heavily to greenhouse gas emissions, microplastic pollution, and toxic water contamination (Niinimäki et al. 2020).

Fast fashion's rapid production cycles have accelerated this impact, enabling low-cost garments at the expense of ethical labour and environmental integrity. Although sustainability has become a widely adopted marketing term, transparency within the supply chain remains fragmented and largely unverifiable. Consumers encounter inconsistent labeling systems that fail to communicate a product's actual ecological or social footprint, leading to widespread confusion and mistrust.

As global awareness grows, design practitioners are being called upon to bridge the information gap between industry and public understanding. Policy frameworks such as the European Union's *Digital Product Passport* initiative signal an institutional push toward transparency, yet their success depends on effective communication design. This intersection between sustainability policy, digital innovation, and human-centred design forms the foundation of this research.

The Conscious Choice project explores how design can become an active agent in transforming fashion's accountability. It investigates the role of universal visual language, UX design, and data accessibility in shaping responsible consumer behaviour. The research draws upon mixed methods: qualitative interviews with industry experts, communication designer Davide Colla and footwear designer Daniel Shirley, and quantitative survey data from seventy-five respondents worldwide. These findings revealed a persistent gap between consumers' awareness of environmental impact and their purchasing decisions, underscoring the need for accessible, credible information at the point of sale.

This paper proposes a universal labeling system as a communication tool and design framework to address that gap. Rather than relying on fragmented brand initiatives, it introduces a cohesive model where every garment can disclose key sustainability indicators through a standardized label and digital extension. The goal is not only to inform but also to empower both designers and consumers to make choices aligned with circular economy principles. By reframing transparency as a *design problem*, *The Conscious Choice* positions communication design as a catalyst for systemic change toward a sustainable fashion future.

2. Literature Context

2.1. Sustainable Fashion and the Transparency Problem

Over the past two decades, *sustainable fashion* has evolved from a niche concern to a central issue in design and manufacturing. It encompasses practices that minimize ecological damage, ensure ethical labour conditions, and promote resource efficiency (Saricam and Okur 2018). However, despite the rise of 'eco-fashion' and 'ethical fashion' discourses, systemic challenges persist. The fashion industry still produces more than 80 billion garments annually, consuming an estimated 79 trillion litres of water and generating 92 million tonnes of textile waste (Niinimäki et al. 2020). Synthetic fibres such as polyester, derived from petroleum, account for over 70% of textile production, contributing to microplastic pollution in aquatic ecosystems (Microplastics in Our Nation's Waterways 2016).

While many brands have launched sustainability campaigns, the lack of transparent communication about materials, manufacturing processes, and supply chains has led to 'greenwashing', the strategic use of sustainability claims for marketing purposes without verifiable evidence (Claxton and Kent 2020). Fashion labels often display vague or misleading sustainability symbols that confuse consumers rather than inform them. As a result, there is a widening trust gap between brands' environmental messaging and the public's perception of authenticity.

2.2. The Circular Economy and Digital Transformation

A growing body of research highlights the circular economy as a framework for reducing waste and closing resource loops. The Ellen MacArthur Foundation defines the circular economy as a system that "eliminates waste and pollution, circulates products and materials, and regenerates nature." In fashion, this involves designing garments for durability, repair, reuse, and recyclability (Mazharul 2022). Yet, circularity requires both structural and behavioural change: the integration of digital tools for traceability and the adoption of consumer-facing communication that explains the lifecycle of products.

Digital innovation provides the infrastructure to make circular systems operational. Technologies such as blockchain, QR codes, and the forthcoming *EU Digital Product Passport* enable real-time visibility across production networks, while virtual try-ons, 3D design, and augmented reality reduce sampling waste (Huynh 2021). According to Lüdeke-Freund et al. (2019), design-led circular business models rely on transparency and data accessibility to influence sustainable consumption. Designers, therefore, become intermediaries who translate complex supply-chain data into human-centred information systems.

2.3. Consumer Behaviour and Information Gaps

Although surveys show rising awareness of sustainability, behavioural change remains limited. A study by Matsapola (2021) and complementary quantitative research conducted for this project found that over 80% of respondents recognize the environmental harm caused by fast fashion, yet fewer than 10% consider sustainability a decisive factor in purchasing. Price, style, and social influence dominate decisions, perpetuating a cycle of overconsumption (Niinimäki 2010). The social media-driven culture of constant novelty encourages impulsive buying and short garment lifespans (Dottle and Gu 2022).

This discrepancy between awareness and action underscores the inadequacy of existing communication systems. Most consumers are unaware of the real costs behind their clothing, including water pollution, toxic chemical exposure, and unethical labour practices (CBC News 2021). Labels rarely disclose such information in an accessible or standardized format. Consequently, there is an urgent need for design interventions that make sustainability data both credible and intuitive.

2.4. Communication Design as a Catalyst for Sustainable Transition

Designers occupy a critical position at the intersection of creativity, communication, and ethics. Sustainable design extends beyond material choice; it involves reshaping systems of meaning and decision-making (McLennan 2004). As Claxton and Kent (2020) argue, designers can redefine consumer perception by embedding sustainability narratives into visual identity and product communication. The *Triple Bottom Line* model – profit, people, and planet – has evolved into a communication framework for brands aiming to balance economic success with environmental and social responsibility (Elkington 1997).

In the context of fashion, visual communication can bridge the gap between information complexity and user comprehension. Campaigns like Vivienne Westwood's collaboration with Kenyan artisans (Corà 2021) or Patagonia's "Don't Buy This Jacket" initiative exemplify how messaging can promote responsible consumption. Yet, these examples remain fragmented brand efforts. A universal, standardized labeling system, integrated across the industry, offers a scalable solution to convey verified sustainability metrics in a transparent, data-backed manner.

2.5. Toward a Universal Labeling Framework

Emerging policies such as the EU's *Digital Product Passport* and the *Corporate Sustainability Reporting Directive* (European Commission 2020) reflect growing regulatory interest in product traceability. However, these frameworks often lack user-centred design considerations. The complexity of data presentation can alienate everyday consumers, reducing engagement. By aligning with design principles of clarity, hierarchy, and inclusivity, labeling systems can transform regulatory compliance into an educational and empowering tool.

The Conscious Choice framework positions communication design as the missing link in this ecosystem. By synthesizing data-driven transparency with visual design, it envisions a universal language for sustainability, bridging the gap between industry accountability and consumer comprehension. This literature foundation establishes the theoretical and ethical rationale for developing such a design system, explored further in the next sections of this paper.

3. Methodology

This research adopted a mixed-method approach, integrating qualitative and quantitative techniques to explore how design and digital innovation can enhance transparency and sustainability in the fashion industry. The methodology aimed to understand both industry perspectives and consumer attitudes toward sustainable fashion and to inform the design of *The Conscious Choice* universal labeling system.

3.1. Research Design

The study was structured around two complementary research strands:

1. **Qualitative inquiry** through semi-structured interviews with design professionals to gain insight into the role of sustainability and technology in contemporary fashion practice.

2. **Quantitative analysis** via a survey targeting general consumers to evaluate awareness, behaviour, and preferences regarding sustainable fashion and communication systems.

This combination provided a holistic understanding, linking the design process and communication challenges faced by practitioners with the behavioural realities of consumers.

3.2. Qualitative Research: Expert Interviews

Two in-depth interviews were conducted with professionals representing distinct yet interconnected fields of fashion design:

- Davide Colla, a Milan-based designer and creative director at the award-winning agency *150UP*, and co-founder of a fashion label, shared perspectives on the integration of sustainability within brand communication.

- Daniel Shirley, a footwear designer at Puma and creator of the 3D-printed shoe *Mule 1* in collaboration with Zellerfeld, provided insights into sustainable product design, material innovation, and the use of 3D printing as a zero-waste manufacturing method.

Each interview followed a semi-structured format with ten guiding questions that examined how design agencies and product designers address sustainability, innovation, and digital transformation. Conducted virtually via Zoom, the interviews allowed for flexible discussion and reflective analysis of personal experience and professional practice.

Key insights emerged from both participants. Davide Colla emphasized that **authentic sustainability communication** only becomes a priority when it aligns with a brand's core identity. He identified **augmented reality (AR)** and **virtual fittings** as transformative tools capable of reducing material waste through digital sampling. He also highlighted that while artificial intelligence is reshaping creative workflows, it must be integrated ethically, as a support to, not a replacement for, human design thinking.

Daniel Shirley provided a product-focused viewpoint, detailing how footwear design remains constrained by traditional multi-material constructions that hinder recyclability. He described 3D printing as a circular design opportunity, enabling on-demand, factory-free production with minimal waste. However, he noted that the industry still prioritizes performance and aesthetics over sustainability, and that consumer affordability remains a decisive factor. His reflections on single-material shoes, mechanical versus chemical recycling, and emerging bioplastic alternatives informed the functional parameters of *The Conscious Choice* labeling system, particularly the need to communicate material composition and recyclability in plain, comparable terms.

3.3. Quantitative Research: Consumer Survey

To complement the qualitative data, a survey of seventy-five participants aged 18-60 was conducted using the SurveyPlanet platform. The questionnaire comprised 23 multiple-choice questions, including three demographic items and twenty exploring awareness, attitudes, and habits related to sustainable fashion and technology-enabled transparency. Participants represented a diverse geographic background, offering a global perspective on consumer behaviour.

Results revealed that 82.7% of respondents were aware of the environmental impact of fast fashion, yet fewer than 7% actively verified whether a brand followed sustainable practices before purchasing. The majority prioritized price, style, and availability, while only a small fraction checked product labels for sustainability claims. More than half (52.9 %) admitted owning numerous clothing items they seldom wore, underscoring a pattern of over-consumption despite awareness.

Notably, 68% observed an increase in sustainability-related messaging and visuals on clothing labels or advertising, yet many still could not name a single sustainable brand. While a minority (22.7%) reported shopping at second-hand stores, most participants expressed interest in digital innovations, such as virtual fitting and 3D-printed, recyclable footwear, signaling a readiness to engage with technology-driven sustainability solutions.

3.4. Data Synthesis and Design Implications

The integration of qualitative and quantitative findings provided actionable direction for the design phase. Interviews illuminated industry challenges and opportunities, while the survey exposed communication gaps and behavioural contradictions. Together, these insights informed *The Conscious Choice* system's emphasis on clarity, verification, and education, translating complex sustainability metrics into an accessible, visual language that bridges brands' transparency efforts and consumers' decision-making.

4. The Design Solution: The Conscious Choice Labeling System

4.1. Concept Overview

The Conscious Choice labeling system was conceived as a design-driven response to fashion's transparency crisis, aiming to make sustainability data accessible, verifiable, and meaningful to consumers. The project originated from the insight that although awareness of sustainable fashion is increasing, the lack of standardized communication prevents informed decision-making. Existing labels, such as 'eco,' 'green,' or 'ethical', are inconsistent, often brand-specific, and seldom based on measurable criteria. This ambiguity reinforces consumer mistrust and limits progress toward circular economy goals.

The proposed system introduces a universal labeling framework applicable across brands, garments, and digital platforms. By merging UX design principles, data visualization, and circular economy metrics, the system enables a consistent way to disclose key sustainability indicators for each garment. It translates technical lifecycle data into an intuitive visual language that informs rather than overwhelms.

4.2. Design Objectives

The design process followed a human-centred methodology guided by three core objectives:

1. **Transparency and traceability:** to make supply-chain data visible and verifiable at the product level.

2. **Comprehensibility:** to simplify complex sustainability information through hierarchy, colour coding, and iconography.

3. **Empowerment:** to support behavioural change by providing consumers with reliable information for conscious purchasing.

These principles align with the United Nations Sustainable Development Goals (SDG 12: Responsible Consumption and Production) and the EU Digital Product Passport initiative, ensuring that the system contributes to broader sustainability frameworks.

4.3. System Structure

The labeling system operates on two levels:

Physical label (front-facing communication):
A compact, visually clear tag attached to garments, designed for immediate understanding. It features:

- **Sustainability score (A–E rating)** based on verified lifecycle metrics such as carbon footprint, water use, and labour ethics;
- **Three primary indicators** *Environmental Impact, Social Responsibility, and Production Transparency*, each represented through color-coded icons;
- **QR code integration**, linking to a digital extension for deeper information.

-

Digital layer (extended transparency):
When scanned, the QR code directs users to an online product page where detailed data is presented, including:

- full supply-chain traceability map;
- material composition and recyclability index;
- production site certifications (Fairtrade, GOTS, OEKO-TEX);
- repair and reuse guidelines;
- end-of-life disposal or return options.

-

The visual interface of the digital layer follows principles of clarity, consistency, and inclusivity, using readable typography, intuitive icons, and colour accessibility standards.

A	B	C	D	E
A - Exceptional Sustainability and Safety:	B - High Sustainability and Safety:	C - Moderate Sustainability and Safety:	D - Limited Sustainability, Moderate Risk:	E - Unsustainable and Potentially Harmful:
Materials:	Materials:	Materials:	Materials:	Materials:
Organic cotton: 80%	Organic cotton: 60%	Conventional cotton: 50%	Conventional cotton: 70%	Conventional polyester: 60%
Hemp: 10%	Bamboo: 20%	Bamboo: 20%	Polyester: 15%	Conventional cotton: 30%
Tencel: 5%	Tencel (Lyocell): 10%	Recycled polyester: 15%	Rayon: 10%	Rayon: 5%
Recycled polyester: 5%	Recycled polyester: 10%	Tencel (Lyocell): 15%	Some recycled content: 5%	Synthetic additives: 5%
Environmental Impact:	Environmental Impact:	Environmental Impact:	Environmental Impact:	Environmental Impact:
Renewable and organic materials: 95%	Certified organic and recycled materials: 80%	Eco-friendly materials with room for improvement: 70%	Conventional materials with significant impact: 70%	Use of conventional materials with high impact: 100%
Minimal impact on ecosystems: 5%	Sustainable dyeing processes: 20%	Basic waste reduction: 30%	Limited use of eco-friendly practices: 30%	Limited or no sustainable practices: 100%
Skin Safety:	Skin Safety:	Skin Safety:	Skin Safety:	Skin Safety:
Certified organic fibres: 80%	Low-risk materials: 60%	Generally safe for normal skin sensitivity: 50%	Moderate risk of skin irritation: 60%	Potential harm due to harmful chemicals: 100%
No synthetic or harmful dyes: 20%	Low-impact dyes: 40%	Limited use of potentially irritating substances: 50%	Materials may contain some harsh chemicals: 40%	Not recommended for sensitive skin: 100%
Lifetime:	Lifetime:	Lifetime:	Lifetime:	Lifetime:
Up to 6 years	3-5 years	Up to 3 years	Up to 2 years	Up to 1 year

Table 1: Sustainability grading matrix (A-E) defining material composition, environmental impact, skin safety, and product lifetime categories within The Conscious Choice system. Credit: Vicky Tsiachri

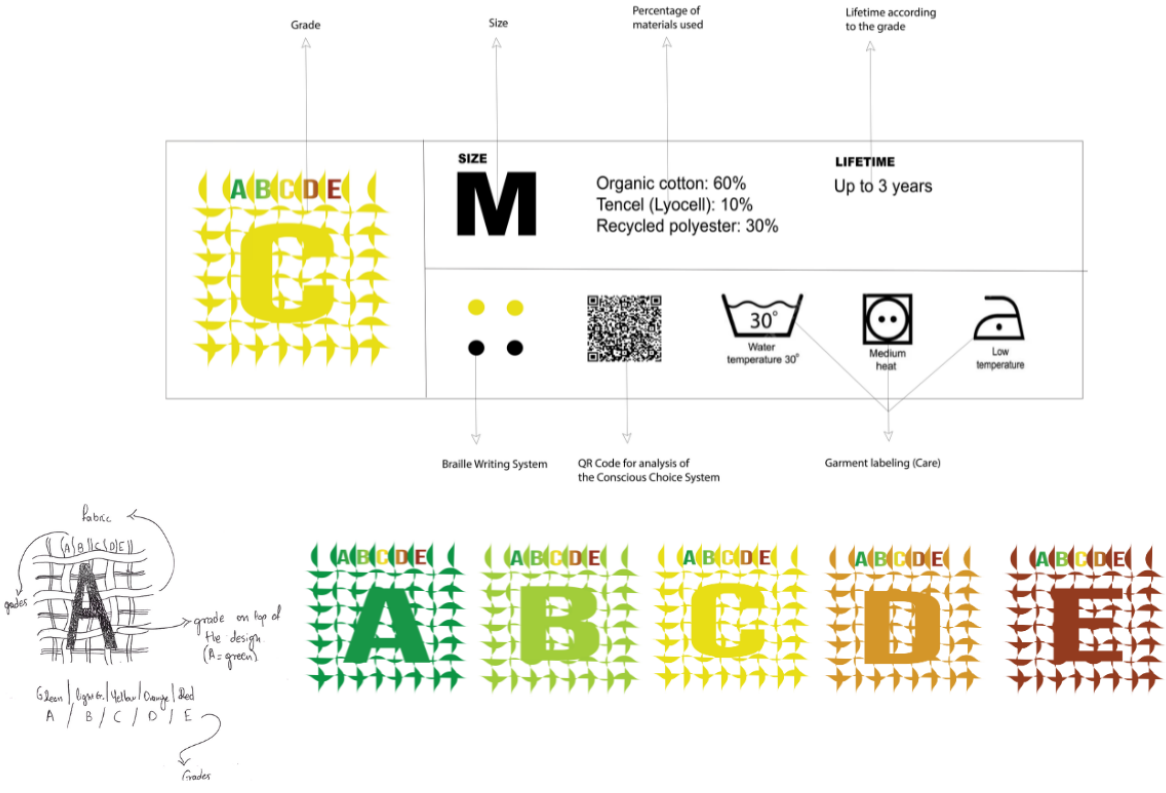

Figure 2: *The Conscious Choice* labeling system (integrated diagram showing label structure, sustainability grading scale A–E), and material transparency indicators. Credit: Vicky Tsiachri

4.4. Design Development and Prototyping

The design phase evolved through iterative prototyping guided primarily by the research findings and the identified need for accessible sustainability communication. Insights from the multi-method research reinforced the premise that sustainability communication must balance credibility with creativity. The professional perspectives gathered through interviews, on storytelling in brand identity and the potential of technological innovation for waste reduction, validated the broader design rationale.

Early prototypes explored different combinations of visual hierarchies, balancing minimalism with informativeness. Through feedback and reflective evaluation, the design adopted a green-to-red colour scale for quick environmental comprehension, paired with neutral backgrounds to ensure legibility across product types. This visual logic was inspired by existing European communication models, notably the Nutri-Score system used in Germany and the EU Energy Efficiency label, both of which successfully translate complex quantitative data into intuitive, colour-coded scales for public understanding. Each indicator uses a concise icon (e.g., a droplet for water, a leaf for renewability, a globe for carbon footprint) accompanied by a brief numeric score or qualitative descriptor.

Each colour category within *The Conscious Choice* label (Table 1) corresponds to a quantitative sustainability grade, ranging from A (exceptional sustainability and safety) to E (unsustainable and potentially harmful). Each grade includes three subcategories, materials, environmental impact, and skin safety, providing a multidimensional assessment of a garment's overall performance.

For example, category A represents garments made primarily from renewable or organic materials (up to 95%), minimal ecosystem impact, and certified non-toxic fibres with a lifespan of up to six years. In contrast, category E indicates products relying almost entirely on conventional or synthetic materials with high ecological and health risks, and an average lifespan under one year.

This tiered scoring model makes sustainability data tangible and comparable at a glance. Inspired by Nutri-Score and EU Energy Efficiency labels, it adapts their colour-coded approach to the context of fashion sustainability. By including measurable subcategories under each colour, the system encourages both brands to improve their metrics and consumers to make informed, conscious choices.

4.5. Data Framework and Verification

The credibility of *The Conscious Choice* label depends on verifiable data sources. The system is designed to integrate with third-party certification databases and emerging policy standards such as the EU Digital Product Passport (DPP). By aggregating data through standardized APIs, the label can display verified metrics in real time.

To maintain transparency, each metric is accompanied by a verification icon, a small checkmark symbol identifying whether data was confirmed by a third party, self-reported by the brand, or pending verification. This approach not only encourages honesty among manufacturers but also educates consumers about the reliability of the information they see.

4.6. Inclusivity and Cross-cultural Design

A critical aspect of the system is its universal accessibility. Considering cultural and linguistic diversity, the label avoids text-heavy explanations and instead uses globally recognizable symbols supported by colour and numeric indicators. The goal is to transcend literacy and language barriers, allowing any user, regardless of age, education, or location, to interpret the label easily.

The design also anticipates digital inclusivity, ensuring compatibility with screen readers and accessibility standards for users with colour vision deficiencies. By embedding universal design principles, *The Conscious Choice* aims to function across markets and demographics, reinforcing equity within sustainable communication.

4.7. Outcome and Design Implications

The resulting system represents a communication infrastructure that connects design practice, policy, and consumer behaviour. It demonstrates how UX design methods can transform sustainability data into tangible awareness and influence decision-making at scale. Through iterative research, *The Conscious Choice* evolved into a replicable framework that any fashion brand can adopt or adapt. Its success lies in balancing data precision with emotional resonance, translating abstract sustainability metrics into everyday understanding. The project ultimately redefines transparency as a design challenge, suggesting that visual communication can be a catalyst for accountability and cultural change in fashion.

Image 2: Mock-up visualization of *The Conscious Choice* label applied to a garment, showing physical implementation and user interaction. Credit: Vicky Tsiachri

5. Impact and Discussion

5.1. Transforming Industry Communication

The *Conscious Choice* labeling system has the potential to transform the way fashion brands communicate sustainability. By standardizing how key metrics, such as carbon emissions, material sourcing, and ethical compliance, are displayed, it creates a common visual language that transcends marketing rhetoric. In contrast to brand-specific sustainability icons, this system offers industry-level interoperability, enabling both large corporations and independent designers to disclose comparable data.

This standardization promotes accountability within supply chains. Brands that adopt transparent labeling must rely on verified data, incentivizing traceability and responsible production. Moreover, because the label's framework aligns with the EU Digital Product Passport (DPP) initiative, it can seamlessly integrate into evolving legal requirements for sustainability reporting. This positions *The Conscious Choice* not only as a design concept, but as a policy-ready communication tool adaptable to future regulatory frameworks.

The *Conscious Choice* system was designed to be flexible and adaptable across different fashion sectors, ensuring that brands of any size or capacity can gradually adopt transparent communication practices. Its modular structure allows each company to begin by sharing essential sustainability indicators, such as material origin, production impact, or recyclability, and expand over time as more verified data becomes available. This scalability supports consistent and comparable communication across the industry, encouraging a collective transition toward transparency as an integral part of design practice rather than a marketing strategy.

5.2. Influencing Consumer Behaviour

From the user's perspective, the *Conscious Choice* label acts as an educational interface that redefines how sustainability is perceived at the point of sale. The inclusion of easily interpretable indicators, supported by colour coding, symbols, and ratings, enables quick yet meaningful comparisons between products. This visual immediacy is crucial, as most purchase decisions occur within seconds.

The system's design responds directly to the survey insights that revealed a discrepancy between awareness and action: while most consumers acknowledge fashion's environmental harm, few translate that awareness into sustainable purchasing. By embedding information into the purchase experience, the label reduces cognitive effort and nudges consumers toward more responsible decisions. This aligns with behavioural design theory, which suggests that simplifying complex information through intuitive design can foster sustainable habits (Thaler and Sunstein 2008).

Furthermore, by integrating digital interactivity through QR codes, users are invited into a deeper learning process, discovering the story behind their garments, production locations, and recycling options. This participatory transparency fosters a sense of agency and emotional connection, reframing sustainability from obligation to empowerment.

5.3. Bridging Design and Policy

The *Conscious Choice* system also illustrates how design can mediate between policy intent and public understanding. Many regulatory initiatives, such as the EU Strategy for Sustainable and Circular Textiles, risk losing impact when technical language is not translated into user-friendly communication. Designers, as interpreters of complex information, can bridge this gap through visualization and narrative framing.

By operationalizing sustainability metrics into a human-centred interface, *The Conscious Choice* contributes to what Fry (2009) calls "design for sustainment", design that sustains cultural and ecological systems rather than merely mitigating harm. It exemplifies how communication design can transform policy compliance into meaningful user experience.

5.4. Ethical and Social Implications

Beyond environmental considerations, the system underscores the ethical dimension of information accessibility. In many markets, consumers lack the tools to distinguish between authentic sustainability and misleading claims. Establishing a universal labeling framework democratizes access to information, promoting equity in decision-making and reducing the asymmetry of knowledge between corporations and the public.

However, the implementation of such systems requires vigilance to prevent misuse. Transparency must not become another marketing tool but remain grounded in measurable truth. Designers hold responsibility for maintaining the balance between clarity and complexity, ensuring that simplification does not oversimplify reality.

6. Conclusion

The *Conscious Choice* project demonstrates how design can play a pivotal role in addressing one of fashion's most urgent challenges: transparency. Grounded in design research and informed by both industry insights and consumer data, the study identifies the absence of a unified communication framework as a critical barrier to sustainable transformation. Through the development of a universal labeling system, it translates complex sustainability information into a clear, verifiable, and emotionally resonant format that supports conscious decision-making.

This paper argues that designers are not merely visual stylists but strategic intermediaries, capable of connecting policy, technology, and human understanding. By aligning the labeling framework with the EU Digital Product Passport, the project positions design as a bridge between regulation and real-world engagement. The system's modular, accessible structure ensures that transparency becomes not a competitive differentiator, but an industry norm that empowers both producers and consumers.

Beyond its functional outcome, *The Conscious Choice* contributes a methodological model for research-led design practice. Its integration of mixed methods, qualitative interviews, quantitative surveys, and iterative prototyping, illustrates how evidence-based design can generate actionable solutions with measurable social impact.

In a broader sense, the project reaffirms that sustainability is fundamentally a communication problem as much as a production one. By redesigning how information is delivered and perceived, designers can transform awareness into action and ethics into everyday experience. The future of fashion transparency depends not only on data systems or materials innovation, but on the ability of design to make truth visible, an act of responsibility, creativity, and collective consciousness.

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Cultural Knowledge as Circular Resource: Integrating GenAI and Boundary Objects for Scalable ICH Innovation

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Abstract

This study addresses the challenge of integrating intangible cultural heritage (ICH), with its often tacit and embodied knowledge, into contemporary circular design frameworks. It proposes Generative Artificial Intelligence (GenAI) as a semantic engine to reinterpret ICH as a recyclable and shareable cognitive asset, enabling the circular flow of cultural knowledge. The research examines how GenAI, structured by boundary objects, can facilitate the semantic reuse of cultural narratives while supporting interdisciplinary co-creation and preserving cultural meaning. The methodology involved a four-day interdisciplinary workshop focused on Dong brocade, a Chinese ICH textile. Participants from design, computing, and cultural studies were divided into culturally driven and technologically driven teams. They utilized a toolkit of boundary objects to structure collaboration and mediate between disciplines. Results showed that culturally driven teams, by anchoring GenAI outputs to defined cultural narratives, achieved high authenticity and conceptual clarity. In contrast, technology-driven teams produced visually diverse but culturally misaligned results. These findings indicate that GenAI serves as an effective mechanism for regenerating cultural knowledge when guided by structured cultural intention. The toolkit of boundary objects was instrumental in mediating communication and minimizing cultural distortion. The study concludes by arguing for the inclusion of intangible cultural semantics as a key dimension of circular design, expanding the concept beyond material flows to cognitive and cultural systems. It positions ICH as a circular cognitive resource and demonstrates that structured, intentional workflows are crucial for using GenAI to create culturally aligned, scalable design solutions.

Keywords: Circular economy, creative industries, design innovation, generative artificial intelligence (GenAI), intangible cultural heritage (ICH).

1. Introduction

As global design embraces circular economy principles, practice is shifting from extractive to regenerative design (Moreno, De los Rios, Rowe, and Charnley 2016). The preservation and transformation of intangible cultural heritage (ICH) are being redefined as regenerative processes grounded in circular logic — emphasizing not only the continuity of traditional craftsmanship, but also its potential for reinterpretation within contemporary social and technological systems. Representing a living embodiment of collective intelligence and aesthetic sensibility, traditional crafts are deeply intertwined with a community's cultural identity and historical memory. The knowledge systems embedded in these crafts are typically characterized by tacit knowledge (Bryan-Kinns, Wang and Ji 2022; Priit-Kalev Parts et al. 2011; Sun, Chen and Liao 2021) — knowledge that is embodied, experiential, and context-dependent. Such knowledge is cultivated through "Learning by Doing" and transmitted across generations via "Master-Apprentice relationships". However, in modern design translation processes, designers often overlook the tacit dimensions that constitute the essence of craftsmanship. This decontextualized mode of translation tends to reduce innovation to superficial stylistic reinterpretation, detaching it from its cultural core and thereby diminishing both the depth and authenticity of design outcomes.

Meanwhile, Beaurain and colleagues (Beaurain, Chembessi, and Rajaonson 2023) argue that the circular economy paradigm encompasses all stakeholders involved in the production–consumption cycle. Similarly, the modern translation of intangible cultural heritage (ICH) is an inherently interdisciplinary and collaborative process that engages cultural scholars, designers, and technologists. Their respective knowledge systems, relationships, and cultural values play a crucial role in the regeneration and transmission of tacit knowledge. However, inherent disciplinary boundaries — manifested through divergent epistemologies, discursive frameworks, and evaluation standards — often create significant barriers to collaboration (Yun, Feng, Chen, Nikzad, and Salehi 2025). As a result, design outcomes frequently struggle to balance "cultural authenticity" with "technological applicability" (He et al. 2023).

The rise of generative artificial intelligence (GenAI) has opened new opportunities for solving these challenges. However, in current practice, GenAI is still mainly seen as a simple image-generation tool, lacking the ability to understand or interpret the complex "Tacit Knowledge" embedded within culture artifacts (Wei 2025). Without proper guidance, technological intervention may even worsen cultural misinterpretation. We contend that the main issue is not just technological but also how to build an effective human–AI collaboration mechanism capable of delivering sustainable and scalable innovation.

To investigate this, our study takes Dong brocade (Dong Jin) as a representative case. As a highly knowledge-intensive traditional craft, Dong brocade weaving requires artisans to rely entirely on their mental visualization of patterns to execute complex geometric compositions without any external aids. This process depends heavily on memory and embodied experience, demanding the weaver to "rehearse in the mind before acting". The knowledge structure is primarily tacit, deeply rooted in the artisan's bodily memory, cultural cognition, and long-term practice. Moreover, its geometric patterning not only represents a distinctive aesthetic system but also functions as a semiotic code, a visual language through which the Dong people convey cosmological beliefs, social structures, and collective memories. These characteristics make Dong brocade an ideal case for studying the transmission of tacit knowledge.

To explore these issues in a real-world context, we conducted a four-day interdisciplinary design workshop (see Image 1). The workshop aimed to examine how GenAI could be more deeply integrated into the innovation process of traditional crafts. Specifically, it sought to develop a new human–AI co-creation framework that enhances the transmission and transformation of tacit cultural knowledge while fostering effective collaboration among multidisciplinary teams.

Image 1: The Dong brocade design works output by each theme group in the workshop.

2. Research Objectives

This study conceptualizes GenAI not as a passive execution tool but as a new type of 'Design Material' that must be deliberately harnessed within the framework of the circular economy for cultural innovation in intangible heritage (ICH). To construct a framework capable of managing this new material, we draw upon Boundary Objects Theory. Within the workshop setting, boundary objects were designed to facilitate effective collaboration among interdisciplinary teams — enabling diverse forms of knowledge, values, and goals to be meaningfully integrated.

Under this collaborative framework, intangible cultural knowledge is no longer treated as a static historical legacy, but rather as a circulating and renewable cognitive asset that can be regenerated and reinterpreted through design innovation. This approach aligns with the regenerative logic of the circular economy while ensuring the continuity and authenticity of culture amid technological mediation.

Accordingly, our research addresses the following questions:

RQ1: In the innovation design of intangible cultural heritage, how can a boundary-object-centred collaborative framework position GenAI as a semantic engine to support the reuse, recombination, and creative reinterpretation of artisans' tacit knowledge within the circular economy paradigm?

RQ2: How can different human–AI collaboration modes, shaped by boundary objects, foster scalable interdisciplinary co-creation between design and technology fields — enabling the regeneration and transmission of cultural heritage while maintaining both its authenticity and creative vitality?

3. Related Work

3.1. The Dilemma of Dong Brocade Digital Transformation: A Circular Economy Perspective

Dong brocade, as part of China's intangible cultural heritage, carries rich regional and ethnic values. Its true worth lies in the complex knowledge embedded in artisan's memory, cultural understanding, and long-term practice, which is hard to document or convey through standardized methods. This makes it vulnerable to semantic loss during digital translation.

Two key features of Dong brocade resist digitalization:

1. Its generative logic, where pattern is structure. Motifs are created during the weaving process, first imagined in the weaver's mind, then translated into precise actions. This close connection between design and execution makes it hard for digital tools to capture.
2. Its cultural semantic system. The motifs are cultural codes, not just decorations, representing the Dong people's cosmology and collective memory. Their use follows a cultural grammar tied to specific social and ritual contexts.

Current digitalization practices largely focus on the visual extraction and reproduction of Dong brocade, employing computer vision algorithms to analyze motifs or training AI models to generate stylistically similar patterns (Yang and Yang 2025). However, such decontextualized approaches reduce a dynamic, living cultural knowledge system into a static repository of visual symbols. Consequently, the resulting 'innovative designs' often degenerate into superficial collages — visually novel but culturally hollow — severed from their organic cultural foundations and prone to misinterpretation or misuse (Bunz 2019).

From the perspective of the circular economy, this dilemma reveals a deeper issue: circularity involves not only the reuse of material resources but also the regeneration of cultural and knowledge capital (Fusco Girard, Nocca and Gravagnuolo 2019). Treating the craft and its materials merely as physical assets for digital archiving neglects the preservation and translation of cultural context, effectively producing cultural waste — symbolic fragments stripped of meaning that cannot be effectively circulated within the contemporary cultural ecosystem.

The main challenge in Dong brocade's digital transformation is the lack of a framework to effectively translate, preserve, and regenerate tacit cultural knowledge. Future efforts should shift from using technology solely for efficiency to developing integration methods that bridge the gap between traditional craft knowledge and modern digital approaches. This ensures that technological innovation maintains cultural authenticity and vitality, enabling intangible cultural heritage to function as a sustainable cultural asset in modern societies. This is the central issue this research aims to address.

3.2. Generative AI: From Intelligent Tool to Cross-context Collaborator

The rise of GenAI presents unprecedented opportunities for innovation in intangible cultural heritage (ICH) design. Text-to-image models such as Stable Diffusion and Midjourney possess powerful image generation and style transfer capabilities and are increasingly applied to the redesign of traditional patterns (Mengen Gu, Wu and Liu 2023). For instance, researchers have used parameter-efficient fine-tuning methods such as LoRA to generate culturally specific motifs from small datasets (Fomenko et al. 2024), applying them in immersive exhibitions to enhance public engagement with cultural heritage (Chamola et al. 2024).

Yet, most current applications still treat GenAI as a high efficiency 'intelligent tool,' emphasizing automation and productivity. Without deep understanding of the specific cultural contexts, craft logic, and symbolic systems, AI-generated outcomes may approximate authenticity in form while failing semantically — resulting in what we term "simulated pseudo-innovation" (Dai, Feng, Wang and Jung 2024). This problem arises because existing models struggle to capture or enact the implicit authenticity constraints embedded within traditional craft transmission (Spennemann 2023).

To address this limitation, recent research highlights the explicit representation of tacit knowledge as a key entry point. Frankjær and Dalsgaard (2022) proposed an interaction framework based on craft processes that captures non-verbal knowledge through video, sensory data, and embodied gestures (Frankjær and Dalsgaard 2018). Similarly, Moradi et al. (2021) found that in pottery studios, artisans effectively structured complex craft workflows using video documentation and "knowledge tagging" systems, improving knowledge transfer and creative reuse (Moradi, Nguyen, Nguyen and Torres 2022). Within HCI, scholars have begun to reconceptualize GenAI not as a tool but as a collaborator (El-Zanfaly, Huang and Dong 2023). This paradigm shift focuses on deeper mechanisms of human–AI co-creation. For example, Guzdial et al. (2019) demonstrated that when AI is framed as a student or partner, designers engage in more reciprocal and exploratory creative dialogues (Guzdial et al. 2019).

Despite this progress, a critical research gap remains: how should human–AI collaboration be structured and moderated? Most studies validate the potential of co-creation or examine specific interaction interfaces but rarely propose a systematic framework to guide interdisciplinary teams — comprising cultural experts, designers,

and technologists — in translating abstract cultural values and tacit craft knowledge into actionable constraints interpretable by AI. This study aims to explore precisely such a framework, ensuring that AI as a collaborator genuinely enables the reuse, recombination, and creative reinterpretation of cultural knowledge.

3.3. Boundary Objects: Constructing Scaffolds for Interdisciplinary Collaboration

Innovation in ICH digitalization inherently involves multiple disciplines — cultural studies, design, and computer science — whose heterogeneous knowledge systems necessitate interdisciplinary collaboration. However, differences in epistemology and language often result in misaligned expectations and communication gaps that undermine project coherence. To address these challenges, Boundary Objects Theory (Leigh Star and Griesemer 1989) provides a valuable analytical lens. Building on this foundation, Carlile (2002) elaborated the concept, defining boundary objects as shared artifacts that can be jointly used by different communities while being interpreted through their respective perspectives (Carlile 2002).

Carlile's typology suggests that different boundary objects support progressively deeper levels of knowledge work, from basic information transfer, through semantic translation, to knowledge transformation (Carlile 2002). This differentiation encourages intentional design and evolution of boundary objects to match distinct collaboration needs across project stages.
Moreover, boundary objects operate not only as surface-level mediators but also as agents of systemic change within cognitive and institutional boundaries (Barrett and Oborn 2010). They translate disciplinary languages (Bechky 2003) and enable sustained knowledge flow across systems, continuously reconstructed and recontextualized through iterative interactions (Leonardi, Bailey and Pierce 2019).

Building on these insights, we identified four prototypical types of boundary objects within our ICH–AI co-design workshop, each corresponding to a distinct level of knowledge work:

1. **Platonic objects**: shared cultural concepts or design visions that align interdisciplinary cognition and collective direction.
2. **Standardized forms**: AI prompt templates, design guidelines, and cultural taboos list that establish a common grammar and reduce miscommunication.
3. **Maps of boundaries**: visual representations such as role maps or process canvases that make collaboration pathways and knowledge boundaries explicit.
4. **Repositories**: databases and semantic knowledge bases that store and share reusable cultural and design assets for ongoing co-creation.

Type	Representative Form	Description	Supported knowledge management type
Platonic Objects	Cultural concept, abstract goal, design goal	Stimulate shared meaning and vision integration among interdisciplinary collaborators	Semantic collaboration and cognitive aggregation.
Standardized forms	Authenticity Elements Of ICH Craftsmanship, AI Prompt Templates, Design Guidelines	Reduce misunderstandings by establishing a common syntax and shared rules	Information transmission and semantic alignment
Maps of boundaries	Role Division, Process Canvas, Structured Design Model.	Visualize knowledge boundaries and flow paths.	Information transmission and semantic alignment.
Repositories	Pattern Database, Reference Case Library, Semantic Knowledge Base.	Provide a multidisciplinary, accessible knowledge resource collection	Continuous collaboration and resource reuse

Figure 1: The identified four typical types of boundary objects in the ICH-AI co-design workshop.

By creating a toolkit of boundary objects, we support interdisciplinary teamwork and human-AI collaboration. This ensures that cultural intentions are accurately translated into actionable forms, guiding AI to generate results that balance authenticity and innovation. This approach provides a strong foundation for collaborative design in intangible cultural heritage innovation.

4. Developing the Workshop

To explore the role of boundary objects in GenAI-driven ICH innovation, the authors used a participatory action research approach. A four-day interdisciplinary design workshop centred on Dong brocade was organized to implement our theoretical framework. They introduced boundary objects as design tools to structure interactions among participants and with GenAI. The focus was not just on producing innovative designs, but on studying how boundary objects mediate the balance between cultural authenticity and technical feasibility.

The workshop was structured into three progressive stages to drive interdisciplinary knowledge integration and creative expression (see Figure 2):

Day 1: Cultural Input and Tool Initiation
Expert lectures established a shared foundation of knowledge about Dong brocade culture, design challenges, and the potential of AI tools.

Days 2-3: Collaborative Creation and Iteration
Participants worked in interdisciplinary teams on co-creation tasks. During this core phase, their design processes were guided through a predefined boundary object toolkit, while the research team closely observed collaborative dynamics.

Day 4: Presentation and Evaluation
Each team presented its final design outcomes, which were evaluated by experts from multiple fields. This stage served to assess the effectiveness of different collaboration models and co-creation strategies.

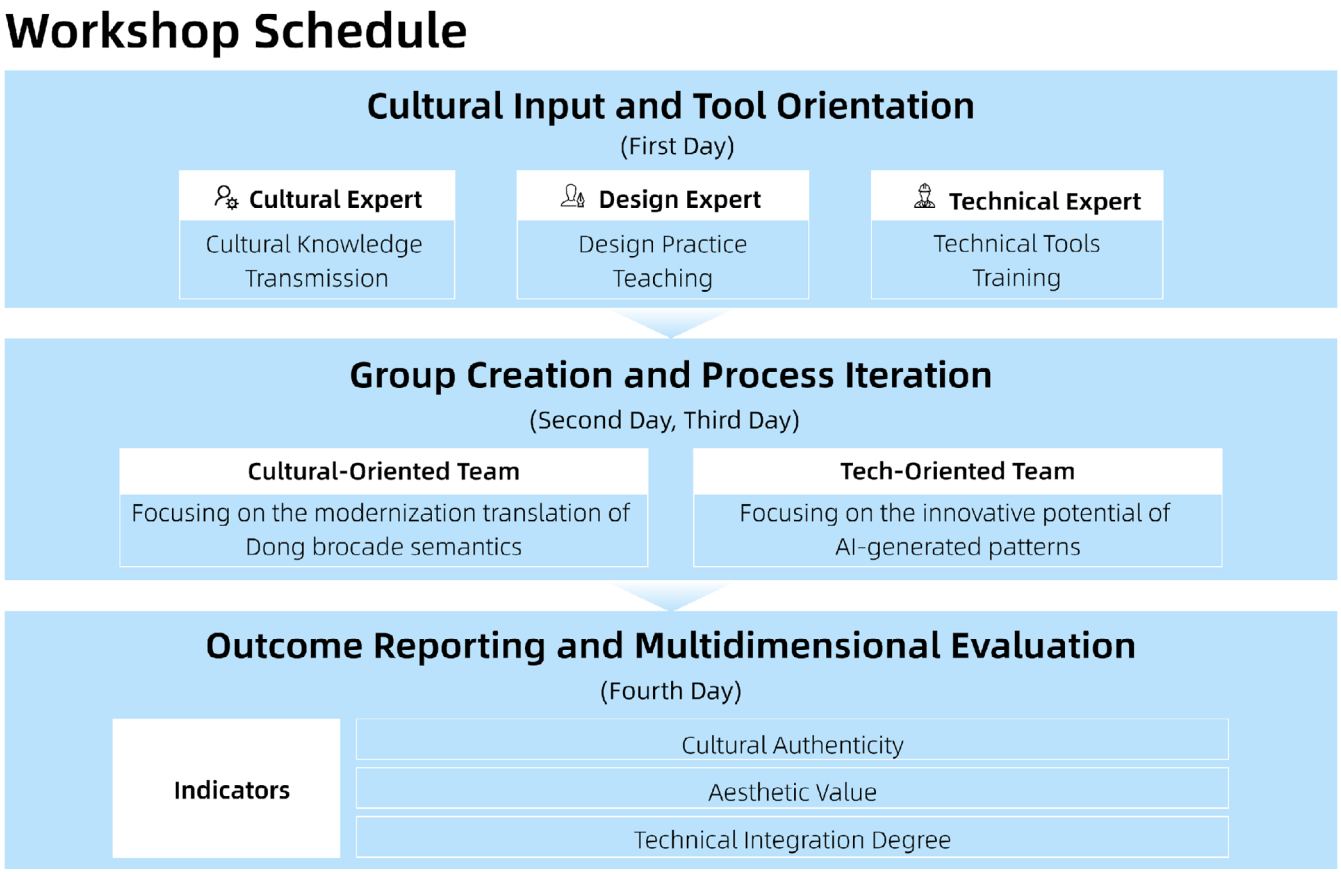

Figure 2: The specific practical process of the 4-day interdisciplinary workshop.

4.1. Participant Recruitment and Grouping Strategy

21 participants were grouped through stratified sampling, focusing on design knowledge, cultural understanding, and AI proficiency. The final group included diverse backgrounds, such as industrial design, digital media, and computer science, ensuring a well-rounded mix.

Participants were assigned to six teams using a heterogeneous grouping strategy: each team included three members with design backgrounds and one with a technical background. This configuration maximized opportunities for cross-disciplinary exchange and knowledge collision (see Figure 3).

Furthermore, to systematically compare how different design orientations influence collaboration modes, the teams were divided into two categories:

1. **Culturally Oriented Teams (COTs)**: tasked with ensuring the faithful translation of Dong brocade's cultural semantics.
2. **Technologically Oriented Teams (TOTs)**: focused on exploring and validating the creative potential of AI-generated patterns.

This quasi-experimental design enabled a comparative analysis of how varying objectives shaped the mechanisms of boundary object use and patterns of human–AI collaboration.

Design Direction	Topic Design	Members	Cultural Knowledge	Design Knowledge	AIGC Knowledge
Cultural-Oriented Team COT	COT-A **Graphic design**	P1	4	5	2
		P2	4	5	5
		P3	2	4	2
	COT-B **Textile design**	P4	4	5	2
		P5	4	5	2
		P6	4	5	2
		P7	1	1	5
	COT-C **Architectural Design**	P8	4	5	2
		P9	4	5	2
		P10	4	5	2
		P11	5	2	5
Tech-Oriented Team TOT	TOT-A **Graphic design**	P12	5	5	2
		P13	5	5	2
		P14	4	5	2
		P11	5	2	5
	TOT-A **Textile design**	P15	5	5	2
		P16	5	5	3
		P17	2	2	5
		P18	2	2	5
	TOT-A **Architectural Design**	P19	1	1	5
		P20	2	5	1
		P21	2	5	1

Figure 3: Basic information of workshop participants, and their heterogeneous grouping based on scores in design knowledge.

4.2. Boundary Object Toolkit as Design Intervention

To examine the operational mechanisms of boundary objects within the design process, we developed a toolkit composed of four types of boundary objects, each designed to provide a structured scaffold for interdisciplinary collaboration. Following Carlile's (2002) typology, these tools correspond to different levels of knowledge work — from high-level cognitive alignment to rule standardization, knowledge integration, and process coordination.

4.2.1. Platonic Objects: Design Briefs as Cognitive Anchors

The first challenge in interdisciplinary collaboration is establishing a shared vision and problem frame. We therefore used design briefs as Platonic boundary objects, serving as cognitive anchors to unify diverse disciplinary perspectives.

In the workshop, we proposed three thematic briefs derived from Dong brocade's cultural essence and potential applications, including visual communication design, modern textile design and architectural decoration design. Each required participants to innovate while maintaining cultural authenticity.

4.2.2. Standardized Forms: Shared Grammar of Design Rules

While design briefs defined what to create, standardized forms addressed how to create, particularly in human–AI collaboration. We developed a design rule system that externalized abstract cultural values and tacit craft experience into standardized constraints understandable by all participants – including technologists. This three-dimensional rule system included:

a) Cultural authenticity rules: specifying acceptable treatments of core Dong brocade elements.

b) Aesthetic consistency rules: distilled from traditional aesthetic principles such as symmetry, rhythm, and colour harmony.

c) Technical reusability rules: providing standardized workflow templates, AI parameter settings, and prompt structures to enhance process efficiency and reproducibility.

4.2.3. Repositories: Creative Resource Packs as Knowledge Hubs

To provide a shared knowledge base, we constructed a creative resource pack functioning as a repository-type boundary object. Its core purpose was to integrate validated cultural knowledge with executable technical guidance, reducing cognitive load and ensuring cultural coherence in design exploration.

The repository contained four key components:

1. AI tool guides and prompt libraries for major platforms (e.g., Midjourney, Stable Diffusion), standardizing human–AI dialogue and lowering technical barriers.
2. A standardized motif database of 75 SVG-format Dong brocade patterns with naming conventions – offering 'cultural building blocks' for creative recombination.
3. Semantic annotation cards, each systematically detailing a motif's symbolism, compositional logic, and cultural context – explicitly linking form and meaning.
4. A design case library, compiling exemplary traditional and contemporary works to serve as inspiration and aesthetic reference points.

4.2.4. Boundary Maps: Co-creation Canvases as Shared Memory

To make the often tacit and complex collaboration processes visible and traceable, we introduced the Co-Creation Canvas as a boundary map. Its core function was to act as a dynamic shared memory, visualizing the team's design trajectory to support collective sense-making, negotiation, and later reflection.

The canvas was structured around the Double Diamond model (Discover, Define, Develop, Deliver), providing a systematic recording space. Teams were instructed to document five categories of core information including project goals, AI prompt iteration logic, adjustments to aesthetic principles, role allocation, and key conflicts and resolutions (see Figure 4).

For the research team, this canvas not only facilitated participant collaboration but also served as a primary data collection instrument. By externalizing tacit thought processes, it provided rich, traceable qualitative data on decision paths, human–AI interactions, and negotiation of knowledge conflicts.

Process Record Canvas

Phase	Division of labor	Tool	Effect
Design Discovery (First Morning of Creation)			
Design Definition (First Afternoon of Creation)			
Design Development (Second morning of creation)			
Design Delivery (Second Afternoon of Creation)			

Figure 4: A canvas for documenting the design process based on the Double Diamond model.

4.3. Data Collection and Analysis

To systematically capture and interpret how boundary objects mediated interdisciplinary collaboration, we employed a mixed-methods data collection strategy. Our focus was not merely on the final outcomes but on the processual dynamics of design. The dataset comprised the following components:

Process Artifacts
All six canvases were collected and analyzed as primary evidence for understanding reasoning patterns and the evolution of collaboration modes.

Ethnographic Observations
Two researchers conducted non-participant observations throughout the workshop, recording team interactions with particular attention to: (1) how participants used and negotiated boundary objects; (2) how cognitive conflicts arose and were resolved during AI output evaluation; (3) how design leadership shifted among members of different backgrounds.

Daily Feedback Surveys
At the end of each day, participants completed short questionnaires capturing their immediate reflections on AI's role, collaboration challenges, and the perceived effectiveness of boundary objects.

Focus Group Interviews
After the workshop, a focus group session was held to discuss the cultural appropriateness of AI-generated designs, the practical efficacy of boundary objects, and the future potential of AI–ICH co-design.

The authors used thematic analysis to code all qualitative data. First, they independently analyzed each group's data to construct their design narratives and collaboration patterns. Then conducted cross-case comparisons, focusing on the differences between the culture-oriented group (COT) and the technology-oriented group (TOT). Through continuous cross-validation across different data sources, the team identified key themes regarding the mechanisms of boundary objects and human-AI collaboration, which form the core content of the next chapter.

5. Findings

Through data analysis of the workshop (see Figure 5) we revealed a core finding: the design orientation of the team was crucial in determining the success or failure of the human-AI collaboration model and the final output. The culture-oriented teams (COTs) successfully established a collaborative model characterized by strong human intent and weak AI generation. They prioritized using boundary objects to establish a shared cultural framework, then employed AI as a tool to assist in realizing specific intentions, thereby harmonizing cultural authenticity with innovation. In contrast, the technology-oriented teams (TOTs) fell into a technology-driven dilemma. Lacking cultural anchoring, they prioritized exploring AI's generative capabilities, resulting in aimless trial-and-error with technology, which led to substantial correction costs and poor output quality in the later stages. The next step was to analyze the evolution of these two models according to the design stages and highlight the crucial role of boundary objects in the process.

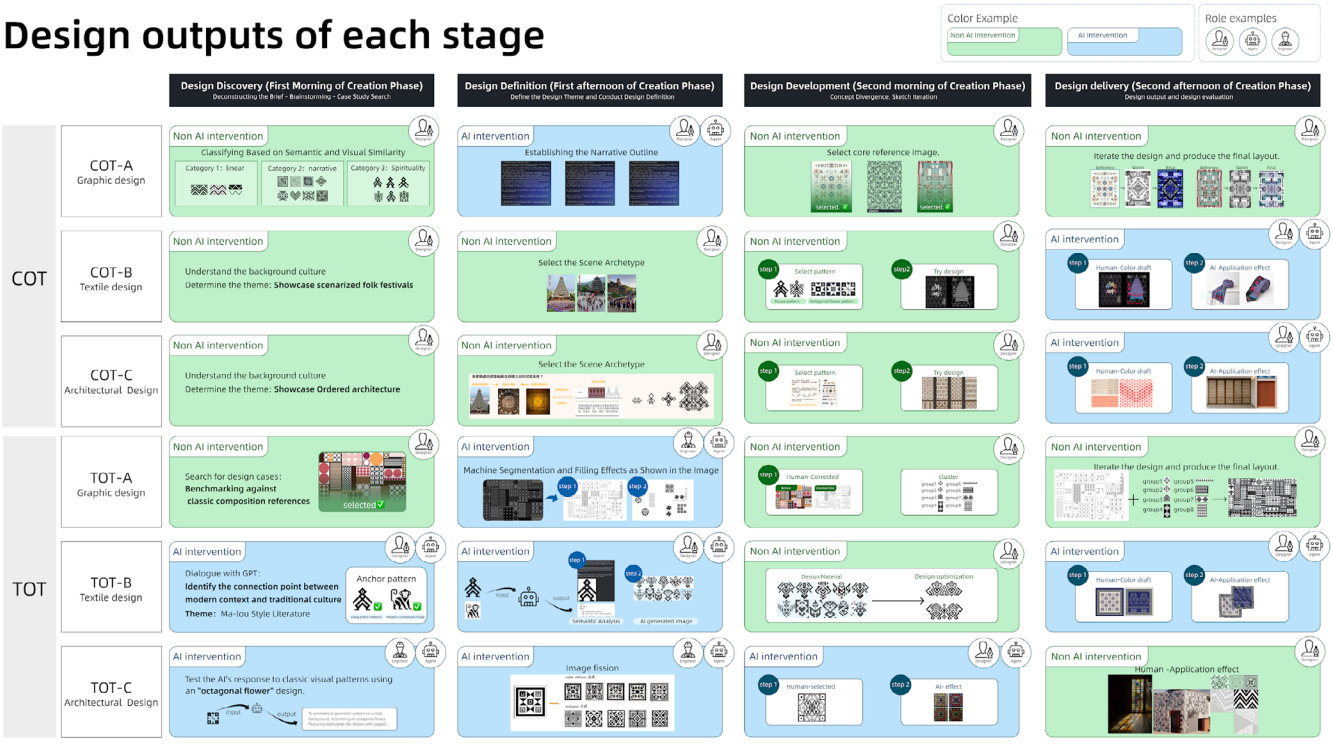

Figure 5: Process documentation from each group across the different workshop phases. The records detail tool usage, interactions with AI, intermediate outputs, and the allocation of roles within the team.

5.1. Design Orientation Differences Driving the Divergence in Human-AI Collaboration Models

5.1.1. Design Discovery Stage: Cultural Anchoring vs. Technological Trial-and-error

In the design discovery phase, the culture-oriented group (COT) and technology-oriented group (TOT) exhibited differentiated collaboration models. The COT group established cultural anchors through boundary objects, beginning with the semantics of Dong brocade motifs, and systematically constructed the mapping relationship of pattern-narrative-scene. For example, the COT-C group used hand-drawn sketches to outline the architectural spatial adaptation logic of the 'Octagonal Flower' motif, employing AI only for local proportion optimization, strictly limiting AI's role to serve specific human intentions. In contrast, the TOT group took the opposite approach, immediately using AI for divergent generations to discover inspiration. For example, the TOT-B group generated over 200 images without sufficient cultural discussion. However, due to the lack of semantic cards and design rules, 68% of their outputs were judged by experts as culturally distorted, as they disrupted the core structure and symbolism of the motifs, as shown in Figure 6.

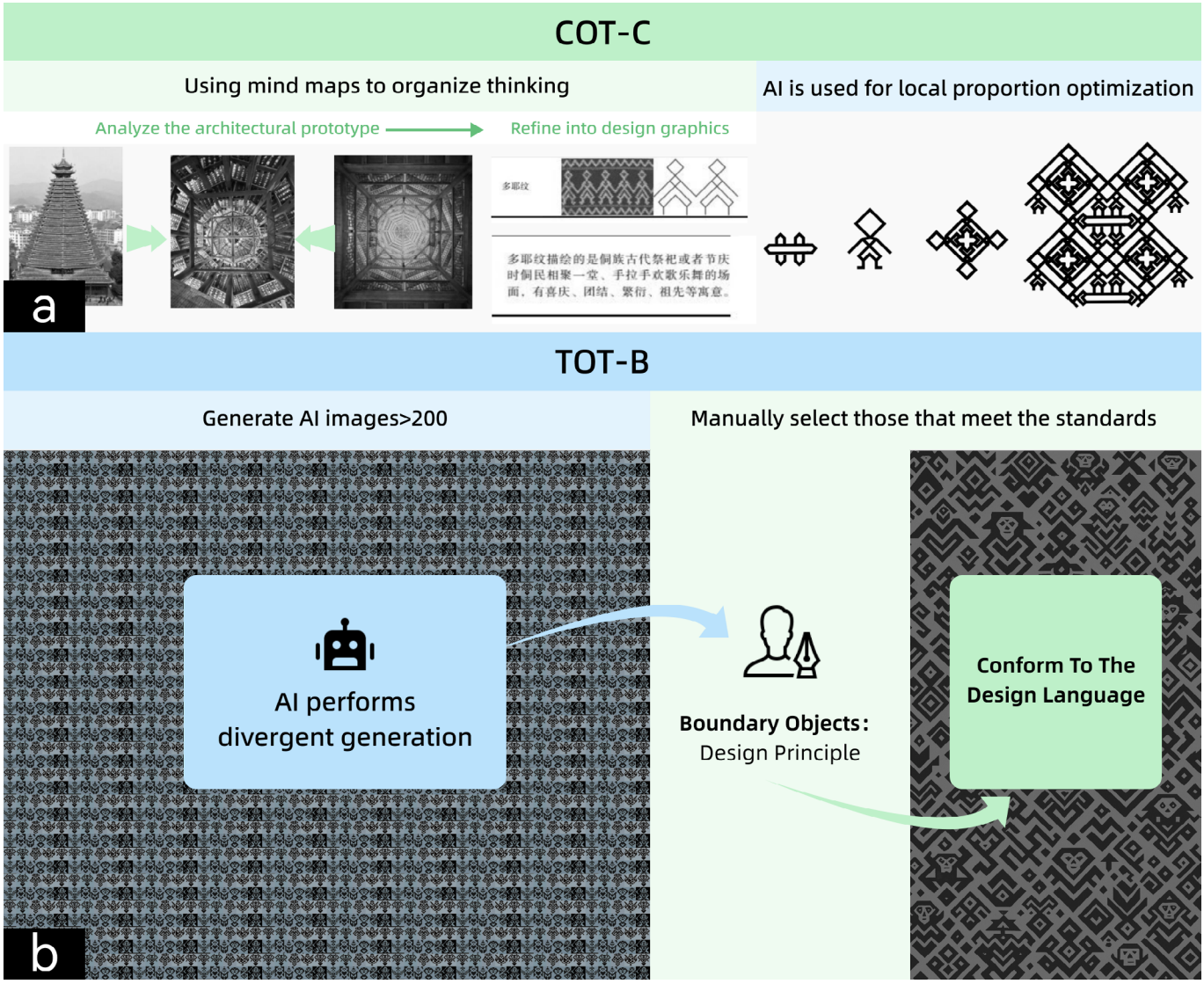

Figure 6: A comparison of design outputs from the discovery phase. (a) Human-led (COT-C): sketches were used to define pattern logic, restricting AI to minor optimization. (b) AI-led (TOT-B): AI generated 200+ images, 68% of which were manually validated as free of cultural distortion.

The COT group avoided cultural misreading by guiding AI with human-driven cultural semantics. In contrast, the TOT group's focus on technology for efficiency led to high output but low quality, creating tension between cultural authenticity and technology, and setting the stage for future cultural-technical debt.

5.1.2. Design Definition Stage: Solidification of Human Decisions and Reconfiguration of Human-AI Struggle

In the design definition stage, the collaboration models of the culturally oriented group (COT) and the technologically oriented group (TOT) further diverged. The COT group solidified the cultural theme through human decisions, narrowing the design space, while the TOT group struggled in the human-AI negotiation, attempting to reconstruct its chaotic technological path.

The COT group further defined its design theme within a strongly constrained cultural framework, including ethnic narratives, festive colours, and architectural order. For example, COT-A group used GPT to generate narrative texts matching the symbolic meanings of the Dongjin patterns, such as 'Duoye', 'Phoenix bird', and 'Fish pattern', thereby establishing a strong ethnic historical heritage design tone. The team then strictly followed the element application guidelines and scene adaptation principles in the creation resource pack, through collaborative discussion, clearly applying the patterns to the cultural scene prototype for dynamic posters, and anchoring the composition to a symmetrical radial logic. During this process, AI tools were used to assist with scene rendering, while team members with design backgrounds took the lead in cultural imagery extraction and visual output control, ultimately ensuring the consistency of cultural accuracy and visual expression.

In contrast, the TOT group fell into a reconfiguration process of human-AI struggle. The team attempted to explore technological boundaries by frequently adjusting prompt weights and combining outputs from multiple models, but this only exacerbated path dependency. TOT-C group found through input condition testing that ordered graphics (such as strictly symmetrical 'octagonal flowers') were more easily recognized by AI and generated patterns closely resembling Dongjin characteristics, with a success rate of 70%. However, among the innovative variations generated from relatively irregular patterns, only 12% passed the cultural suitability review by intangible cultural heritage experts. The results were entirely based on the visual characteristics of the patterns, without considering their cultural semantics, as shown in Figure 7.

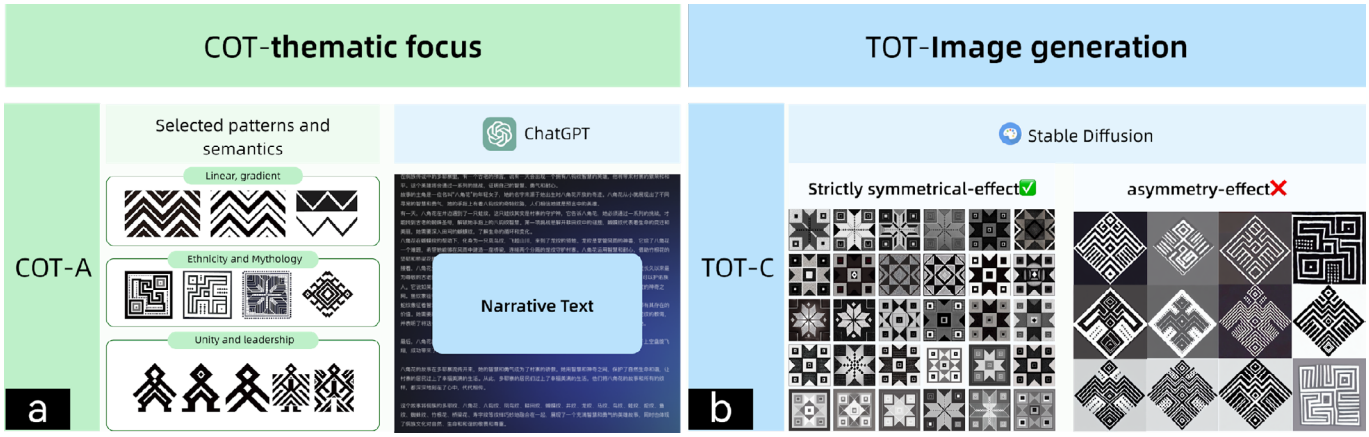

Figure 7: A comparison of design outputs from the definition phase. (a) Human-led (COT-A): AI as an analytical tool, with full manual control over visual design. (b) AI-led (TOT-C): AI-led approach, which excelled with orderly graphics but failed to generate culturally relevant variations from irregular shapes (12% pass rate).

5.1.3 Design Development Stage: Deepening Cultural Logic and Recombining Generated Materials

In the design development stage, the cultural-technical debt accumulated in earlier phases began to have a decisive negative impact on the effectiveness of the TOT group, while the COT group leveraged its solid cultural framework to achieve efficient creative refinement. The COT group shifted its focus to a deeper expression of the cultural logic it had established. For example, COT-A group used ethnic historical narrative as a framework and developed an image logic of symmetry-radiation-layering. They clarified the pattern combination rules through hand-drawn sketches, only using AI to generate 3 basic compositions, with 82% of the drawings done manually. Similarly, COT-C group translated the ordered arrangement principles of Dong ethnic architecture into a flat composition grammar of repetition-gradient-interlacing, driving the innovative evolution of traditional patterns into modern decorations. In the end, 73% of the patterns in their design were rated by experts as "preserving the original features while possessing contemporary aesthetic appeal."

In contrast, the TOT group fell into the predicament of correcting their technological path dependency. Their work was no longer innovative, but rather a remedial recombination of AI-generated materials. TOT-A group manually matched the inaccurate materials generated by the machine in earlier stages, improving visual coherence through cutting, collaging, and layering. TOT-B group extracted graphically stylized symbols, such as the geometric 'monkey pattern', from the generated results and conducted secondary design experiments. Although parameter adjustments improved the regularity of the patterns, the monkey symbol was misinterpreted due to the lack of semantic annotations, leading to lower cultural adaptability of the design. TOT-C group attempted to apply the AI-generated 'ordered octagonal flower pattern' to an architectural scene test. While they achieved 70% visual adaptation using material rendering tools, the design was deemed less feasible due to the neglect of the proportion rules for Dongjin patterns in 3D space, resulting in a low score for practical implementation, as shown in Figure 8.

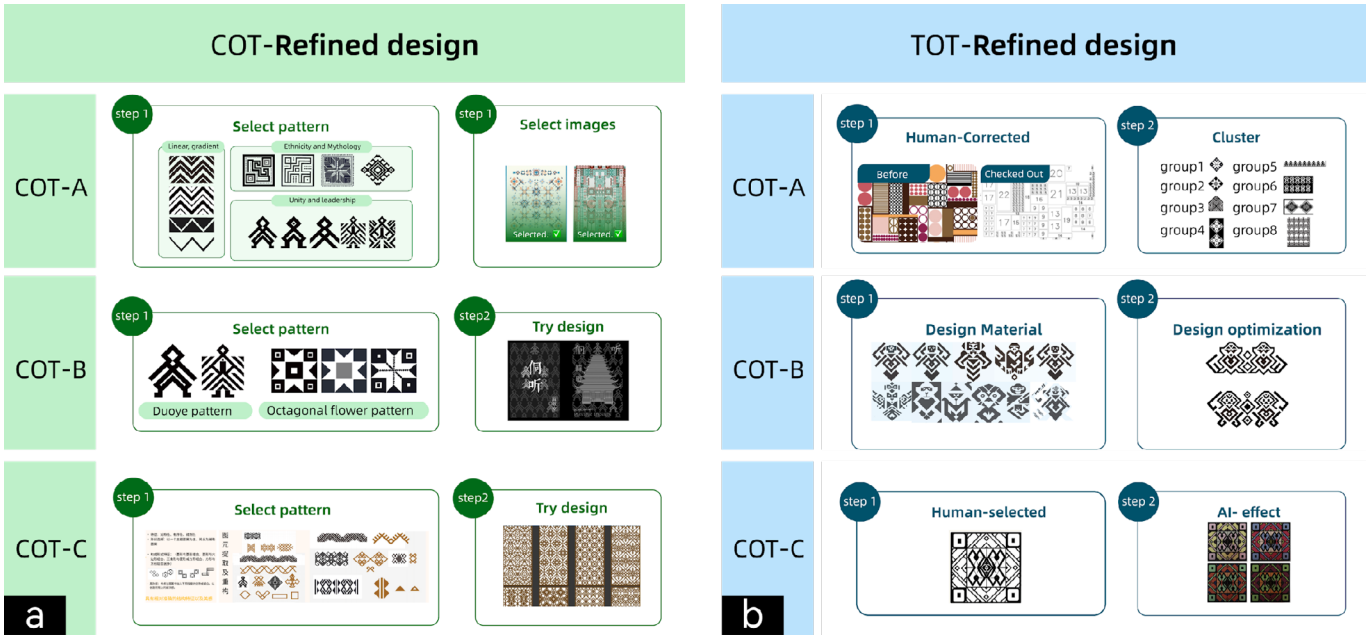

Figure 8: A strategic divergence in the design process. (a) Group COT progressed to the deep expression of its cultural logic. (b) Group TOT, constrained by technology path dependency, shifted to the remedial reorganization of AI assets, stalling further innovation.

5.1.4. Design Delivery Stage: Cultural Integration for Efficiency and Technical Debt Becoming Visible

In the design delivery stage, the differences in collaboration efficiency between the cultural-oriented group (COT) and the technology-oriented group (TOT) became more apparent. The COT group achieved efficient cultural integration, while the TOT group was affected by the accumulated cultural-technical debt. The COT group completed the design efficiently based on its solid cultural framework, with the delivery phase taking up only 28% of the total time, and the cultural authenticity rating remaining stable at 9.2/10. COT-A group successfully fused the 'fish pattern' with the narrative of the Lusheng Festival creating a thematic poster with both cultural depth and visual impact, receiving a high cultural semantic coherence rating of 9.5/10. COT-B group focused on fabric product design, integrating festival scenes with the AI-generated 'sun pattern', manually adjusting the pattern's density to ensure that the fabric texture and Dongjin craftsmanship specifications matched precisely. They ultimately delivered three textile designs that were culturally and functionally adaptable. COT-C group applied Dongjin patterns innovatively to architectural glass windows, with the technical members using AI to efficiently generate multiple material simulations. The design team then led the selection process, optimizing the patterns' proportional relationships in 3D space according to cultural rules. The final designs were highly rated for cultural authenticity (9.2/10) and feasibility (8.5/10).

In contrast, the TOT group spent more time addressing their 'technical debt' during this stage. The delivery phase accounted for 41% of their total time, and much of it was spent on corrections rather than optimization. TOT-A group spent 65% of their delivery time on manual retouching. TOT-C group's design, due to neglecting craftsmanship constraints, had very low feasibility and required a complete manual redo. TOT-A group had to invest 65% of their delivery time into tedious manual line tracing and image editing due to AI-generated patterns lacking style coherence. TOT-C group, although generating visually attractive architectural decoration patterns, failed to adhere to material constraints. As a result, their solution received a very low feasibility rating of 4.3/10 and ultimately required complete manual rework using traditional modeling software, as shown in Figure 9.

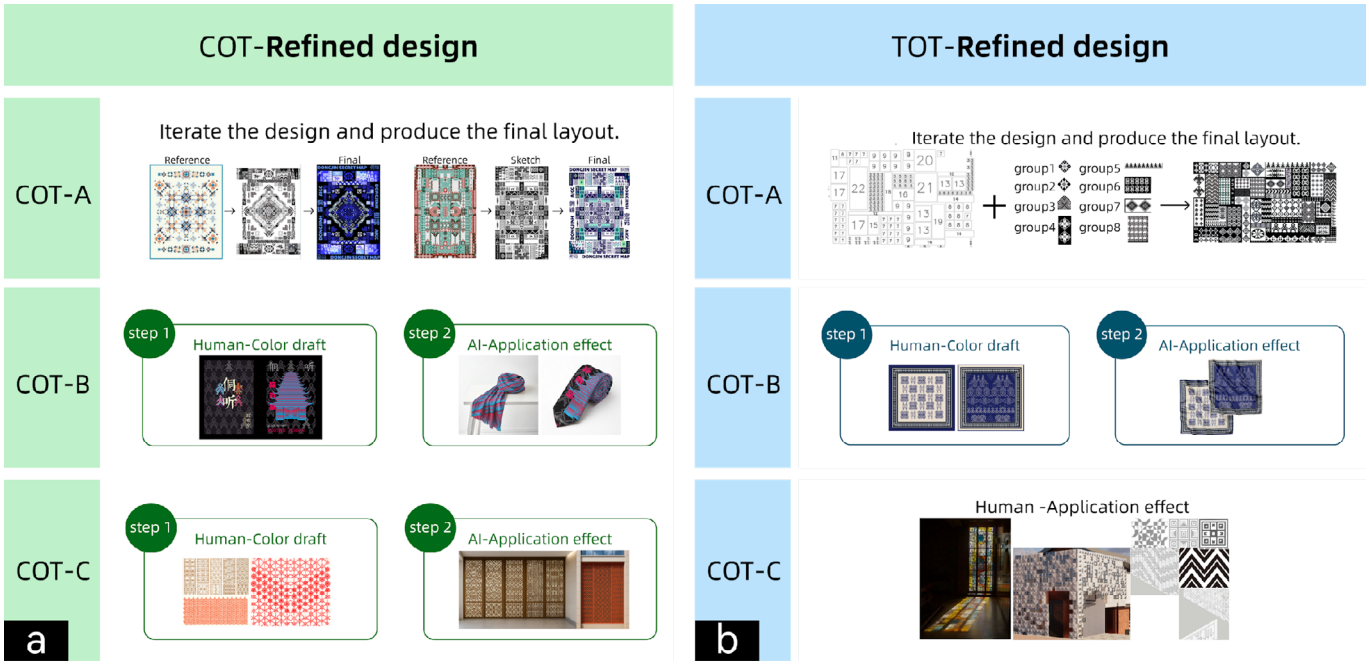

Figure 9: Divergent performance metrics in the design delivery phase. (a) Group COT: Efficient delivery (28% of total time) built on a stable cultural logic, achieving a consistent 9.2/10 cultural authenticity score. (b) Group TOT: High delivery overhead (41% of total time) due to repaying "technical debt," with efforts focused on correction over optimization.

This section compares the collaborative practices of the culture-oriented group (COT) and the technology-oriented group (TOT) across the four stages of Discovery, Definition, Development, Delivery, revealing the evolutionary paths of two distinct human-AI collaboration models. The COT group follows a strong human intent – weak AI generation model driven by boundary objects, ensuring that AI tools remain culturally aligned. This process represents a trajectory of intent convergence through boundary objects. From cultural anchoring in the discovery phase, to logic deepening based on rule systems in the definition and development stages, and efficient integration in the delivery phase, each step is built upon a clear consensus of cultural intent. AI is always placed within a framework constructed by human intelligence, allowing its generative capabilities to be precisely guided and utilized.

In contrast, the TOT group, lacking cultural intent anchoring, falls into a generation equals error vicious cycle. Starting with technological drift in the discovery phase, they struggle with continuous correction and reworking of AI's chaotic outputs in later stages. The more they rely on technology to solve problems, the more cultural errors accumulate, which eventually explode in the delivery phase, resulting in unavoidable high correction costs.

5.2. Boundary Objects: Building the Scaffold for Human-AI Collaboration

The success of the cultural-oriented group (COT) stems from the systematic use of a set of boundary object tools as interventions. These tools are not merely auxiliary materials; they act as scaffolds for building effective collaboration, actively shaping the team's interaction patterns and cognitive frameworks. Through cognitive anchoring, semantic alignment, and process collaboration, these tools provide a ladder-like path for interdisciplinary knowledge sharing, ultimately achieving a dynamic balance between cultural authenticity and technical feasibility.

In terms of the collaborative gain from knowledge sharing, the effect of individual boundary objects is limited, but when combined, they

generate a nonlinear leveraging effect. When the design brief, rule system, and record canvas are organically integrated into the design process, they collectively form a closed loop from high-level intent to specific execution, and then to process reflection. This promotes the transition of interdisciplinary collaboration from basic information transmission to higher-level knowledge co-creation.

This effect is particularly evident in the COT group. The design brief established the cultural direction, the rule system translated it into executable syntax, and the record canvas tracked and visualized the process. These three elements were interconnected, forming a self-reinforcing loop: a clear design brief made the rules more targeted, and well-defined rules provided a solid basis for decisions recorded on the canvas, which, in turn, helped the team track whether they had deviated from the original intent.

In contrast, the TOT group failed to systematically apply these tools, leading to a fragmented collaboration process. Although they used the record canvas, the lack of a guiding rule system led to scattered and illogical recordings, which failed to create an effective shared memory. This shows that the combination of boundary objects, through deep coupling in cognition, semantics, and process, forms a dynamic balancing system that ensures cultural intent always dominates technical generative capabilities.

6. Design Implications and Future Work

The findings of this study not only deepen our understanding of the role of GenAI in intangible cultural heritage innovation but also provide specific and actionable insights for future design education practices and cultural industry practices.

6.1. Implications for Cultural Heritage Innovators

6.1.1. Prioritize Cultural Decoding to Build a Recyclable Tacit Knowledge Foundation

The study found that teams often spent considerable time correcting cultural deviations in AI-generated outputs. Therefore, we recommend systematically conducting cultural decoding at the early stages of the project. By creating semantic cards, design rule sets, and other boundary objects, artisans' tacit knowledge can be transformed into structured semantic resources that GenAI can recognize and process. This upfront investment not only guides the direction of technological exploration but also ensures that craftsmanship logic and aesthetic principles, which are often difficult to articulate, are effectively recycled during the design process, strengthening the cultural legitimacy and authenticity of the generated results from the outset.

6.1.2 Achieving Interdisciplinary Reorganization and Interpretation of Tacit Knowledge

In interdisciplinary teams, boundary objects (such as co-creation canvases and semantic rule libraries) act as shared cognitive scaffolds, effectively bridging the deep knowledge of cultural experts, the creative language of designers, and the technical logic of engineers. These objects not only make abstract cultural knowledge actionable and iterative but also facilitate the continuous reorganization and recontextualization of tacit knowledge throughout the collaboration process. In this context, GenAI serves as a semantic engine, supporting dialogue between different professional perspectives within a shared semantic space, thereby enabling the innovative interpretation and continuous transformation of cultural knowledge during interdisciplinary collaboration.

6.1.3. A Dynamic Human-AI Collaborative Model

GenAI should not be seen as a fully automated tool but as a creative partner supporting the externalization and expansion of tacit knowledge. Successful practices show that in culture-oriented design processes, humans always play the core role in cultural interpretation and aesthetic judgment. The authors advocate for a dynamic human-AI collaborative model: during the creative initiation phase, GenAI is used to inspire and expand possibilities; in the development phase, designers lead the selection, reorganization, and cultural calibration of generated content; and ultimately, humans ensure the authenticity and integrity of the design results within the cultural context. This controlled generative mechanism is key to achieving innovative interpretation of tacit knowledge while maintaining cultural continuity.

6.2. Implications for Design Education and Industry Practice

The insights from this study suggest that future circular design frameworks for intangible cultural heritage must go beyond the material level, placing the flow of intangible resources such as knowledge, identity, and cultural meaning at the core. To achieve this transformation, a collaborative effort between design education, cultural policies, and industry practices is needed, collectively establishing cultural regeneration as a key pillar of circular economy design.

6.2.1. Restructuring Design Education: Cultivating Interdisciplinary Collaborators to Harness Intangible Resources

Traditional design education focuses on the unidisciplinary development of form and function, which struggles to address the complexities of intangible cultural heritage (ICH) innovation. Future education should aim to cultivate multidisciplinary talents capable of navigating the dialogue between culture and technology. This involves a shift in skill development: from single-domain expertise to fostering interdisciplinary collaboration, helping students understand cultural knowledge systems, identity construction, and the logic of meaning generation, while enabling effective communication with engineers and cultural scholars through intermediary models like boundary objects.

6.2.2. Focusing on Cultural Regeneration: Incorporating Meaning Circulation into the Core of Sustainable Design

Design within the framework of a circular economy must create works that not only satisfy modern aesthetics but also achieve cultural regeneration. Design education and practice need to undergo a paradigm shift: expanding the concept of sustainable design from the recycling of physical materials to the regeneration of intangible assets such as cultural symbols, narratives, and aesthetics.

6.2.3. Innovating Industry Practices: Building an Ecosystem that Supports the Flow of Cultural Meaning

The cultural creative industry must go beyond the superficial appropriation of cultural elements and build an ecosystem that supports the continuous flow and regeneration of cultural assets. Industry must explore new business models that effectively enable knowledge reuse, meaning restructuring, and innovative interpretation. New evaluation standards should be established to assess not only economic benefits but also contributions to the continuity of cultural identity, knowledge flow, and meaning regeneration in design projects.

6.2.4. Providing Systematic Support for the Circular Flow of Intangible Resources

Governments and institutions should introduce forward-thinking policies to provide a solid foundation for this paradigm shift. They should develop special policies that prioritize projects with clear cultural knowledge circulation pathways, identity-building processes, and meaning regeneration strategies. Cross-sector funding, platforms, and legal protections should be provided, particularly through mechanisms that safeguard community cultural rights and intellectual property, promoting deep integration between technology, education, and industry under the common goal of cultural regeneration.

7. Conclusion

This study delves into the construction of an effective human-AI collaboration mechanism in the highly sensitive field of intangible cultural heritage innovation. Through an interdisciplinary design workshop centred on Dong brocade, it reveals the cultural-technical debt dilemma faced by a technology-oriented approach (TOT group) and validates the effectiveness of a culture-oriented collaboration model (COT group). The core theoretical contribution is the re-conceptualization of GenAI from a passive tool to an active design material that requires understanding, shaping, and mastery. The research also demonstrated the crucial scaffolding role of boundary objects in this process, effectively bridging cultural semantics with algorithmic logic.

In contrast to previous research on circular design that primarily focused on material flows, this work extends the concept of circularity to the intangible dimension, explicitly proposing that the flow, reorganization, and regeneration of cultural knowledge systems, identity, and symbolic meanings should be at the core of sustainable innovation strategies.

These findings suggest that, within the framework of a circular economy, the deep integration of culture and technology must be the cornerstone of cultural regenerative innovation. This not only provides a new methodological perspective for the survival and evolution of intangible cultural heritage in the digital age but also marks the paradigm shift of circular design from material closed loops to cultural cycles. It lays the theoretical and practical foundation for constructing an innovative ecosystem that is both culturally inclusive and sustainable.

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The DESIGNwith Infinity Loop: A Community-driven Model for Circular Economies for Marginalized Communities and Green Innovation

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Abstract

This paper introduces the DESIGNwith Infinity Loop, a community-driven model integrating employment equity and environmental sustainability to activate local circular economies. Developed by DESIGNwith, a Toronto-based design lab, the model applies participatory design, zero-waste principles, and knowledge-sharing ecosystems to generate both social and ecological value. Tested with immigrant and refugee women, the Loop begins with equitable employment and cycles through skills development, local manufacturing, ESG partnerships, and reinvestment. Through partnerships with The Power Plant Contemporary Art Gallery, Sinai Health Foundation, and CIBC Square, the Loop has demonstrated scalability across cultural, healthcare, and corporate sectors. Its outcomes extend beyond production efficiency to redefine value as care, learning, and agency. The paper argues that the Infinity Loop provides a replicable, people-powered framework linking circular economy theory with lived practice — illustrating how community-led design can drive inclusive sustainability and long-term systems change.

Keywords: Circular economy, community-led design, employment equity, green economy, participatory design.

Introduction

The urgency of the climate crisis has revealed the inadequacy of current economic systems that continue to prioritize efficiency, extraction, and profit over social equity and environmental stewardship. Linear models of production and consumption, the 'take-make-waste' cycle born from the Industrial Revolution, have not only accelerated ecological degradation but also deepened social inequality. As designers, we must ask not only how products are made and disposed of, but also who is included in shaping these systems, and whose voices are silenced in the process.

DESIGNwith was founded to respond to this intersectional challenge by integrating social and environmental impact through design. Based in Toronto (Canada), the lab co-creates sustainable work opportunities for refugee and immigrant women by transforming local waste materials into functional, high-quality products. In doing so, DESIGNwith reimagines design as a participatory and systemic process, not only addressing material waste but also tackling structural inequities embedded in labour, recognition, and economic participation. At its core, the initiative is guided by Humanity-Centred Design (HCD+) principles: addressing root causes rather than symptoms, considering the full ecosystem of stakeholders, taking a long-term systems view, iterating continuously, and designing with rather than for communities.

The Infinity Loop model, introduced by DESIGNwith, builds on circular economy theory while embedding principles of equity, care, and participation. Unlike traditional circular models that emphasize material flows alone, the Infinity Loop highlights the reciprocal relationship between social and ecological systems. By intentionally linking the revalorization of material waste with the empowerment of marginalized communities, the model demonstrates that sustainable economies must be designed as both socially and environmentally regenerative.

This paper situates the Infinity Loop within existing scholarship on circular economy, participatory design, and feminist approaches to labour and sustainability. It then presents DESIGNwith's multi-stakeholder methodology, case studies, and outcomes, illustrating how the model bridges academia, corporations, and communities to create systemic change.

Circular Economy and its Gaps

The circular economy (CE) has emerged as a leading framework for addressing sustainability challenges, promoting strategies such as reuse, recycling, and closed-loop systems (Ellen MacArthur Foundation 2019). CE frameworks argue for the decoupling of economic growth from resource consumption, emphasizing material efficiency, innovation, and business model transformation (Geissdoerfer et al. 2017).

However, critiques of CE highlight its tendency to prioritize technological and material flows while overlooking the social dimensions of sustainability (Murray et al. 2017; Hobson & Lynch 2016). By focusing on corporate efficiency gains, many CE implementations risk reinforcing existing inequalities rather than dismantling them. For example, waste-pickers, garment workers, and immigrant labourers, those most affected by unsustainable production, are often excluded from shaping CE strategies, even though they are most affected by environmental and economic injustices (Gregson et al. 2015).

DESIGNwith responds to this gap by embedding social justice at the heart of circular design. The Infinity Loop moves beyond the narrow emphasis on material circularity to incorporate inclusive participation, equitable labour practices, and cultural recognition as central to sustainability.

Participatory and Humanity-Centred Design

Participatory design has a long history of engaging end-users in the co-creation of technologies, services, and environments, particularly in Scandinavian contexts (Ehn 1988; Sanders and Stappers 2008). More recently, participatory approaches have been reframed as Humanity-Centred Design (HCD+), emphasizing not only human needs but also planetary health, long-term systems thinking, and community-led innovation (Norman 2023).

The benefits of participatory design extend beyond mere inclusivity; not only do they foster a deeper understanding of the complexities inherent in the communities being studied but rather mitigate power imbalances and flatten hierarchy in cross-cultural projects (Constanza-Chock 2020; Qazi 2018). Engaging participants as active contributors in the design process enhances problem-solving capabilities and promotes innovative thinking.

HCD+ principles demand that designers work with communities as co-creators, not beneficiaries, and that they seek to dismantle root causes of inequity rather than addressing surface-level symptoms. This requires building sustained partnerships across institutions, sharing power in decision-making, and recognizing lived experience as design expertise.

DESIGNwith's methodology embodies these principles by flattening hierarchies between "designers" and "non-designers." Refugee and immigrant women sewists are not treated as labourers but as equal contributors whose cultural embroidery, craftsmanship, and lived experiences directly inform design outcomes. This reframing acknowledges that sustainable futures cannot be engineered solely from professional expertise, they must be co-authored with those most impacted by systemic crises.

Feminist Design and Labour Perspectives

Feminist scholars have long critiqued the invisibility of women's labour, particularly in contexts of migration, manufacturing, and care work (Federici 2012; Bhattacharya 2017). Within globalized economies, women often face precarious employment characterized by low pay, little agency, and limited recognition of their skills. The garment industry in particular illustrates how production systems prioritize speed and profit over well-being, often exploiting immigrant and racialized women (Kabeer 2004).

By situating marginalized women at the design table, DESIGNwith directly challenges these dynamics. The lab reframes sewing and embroidery not as low-status, piece-rate labour, but as valuable design expertise that carries cultural, aesthetic, and technical significance. This recognition not only restores dignity and agency to the women involved but also challenges broader economic assumptions about what kinds of work and knowledge are valued.
Through this feminist lens, the Infinity Loop becomes more than a circular material flow, it becomes a model of equitable social reproduction, where care, creativity, and cultural knowledge are central to sustainable economies.

Knowledge Mobilization and Systemic Change

Sustainable change requires not only localized interventions but also mechanisms for knowledge mobilization across scales. DESIGNwith bridges multiple domains (academia, corporate partners, and community organizations) to ensure that learnings are not confined to isolated projects. Public exhibitions, community workshops, and corporate activations function as platforms for education and dissemination, engaging diverse audiences in rethinking waste, value, and inclusion.

This systemic approach resonates with calls for sustainability transitions that combine technological, cultural, and institutional shifts (Markard et al. 2012). By testing and iterating models across different contexts, from art galleries to healthcare to corporate real estate, DESIGNwith demonstrates the scalability and adaptability of the Infinity Loop framework.

The literature demonstrates both the promise and the limitations of prevailing sustainability frameworks. Circular economy offers a powerful vision but risks perpetuating inequities if pursued in isolation from social justice. Participatory and feminist design approaches highlight the need for inclusion, care, and redistribution of power, yet often lack models for integration with material sustainability practices.

DESIGNwith's Infinity Loop addresses these gaps by uniting material circularity with social equity, embedding marginalized voices in the design of sustainable economies, and mobilizing knowledge across institutions. In doing so, it offers a replicable model for systemic transformation, one that treats the health of the planet and the well-being of people as inseparable.

Methodology

Figure 1: DESIGNwith Infinity Loop (2025).

How we Solutioned: Action Research and Co-design

The Infinity Loop model emerged through action research, a methodology grounded in iterative cycles of reflection, collaboration, and experimentation (Lewin 1946; Reason & Bradbury 2001). Unlike traditional research that separates inquiry from practice, action research makes doing central to knowing. This was essential for DESIGNwith, where the goal was not to study marginalized communities but to co-create sustainable pathways with them.

Combined with participatory and co-design practices (Sanders & Stappers 2008), the approach ensured community members were equal contributors, not passive subjects. Projects evolved through continuous feedback loops, from workshops to prototyping to exhibition and evaluation, each strengthening trust, visibility, and collective ownership. *(See Figure 1 for an overview of the Infinity Loop's iterative structure and Appendix A for more detail).*

Community-driven Participation

Refugee and immigrant women were positioned as co-leaders. Many brought informal expertise in sewing and embroidery but faced barriers to formal employment. DESIGNwith reframed these not as deficits but as opportunities to reimagine working structures.

Workshops were designed around participants' family and childcare needs, while translation and peer mentoring supported inclusive decision-making. Cultural craft traditions were recognized as situated design knowledge, enriching circular prototyping with new aesthetic and technical contributions.

Evaluation was similarly participatory: success was measured through qualitative outcomes such as confidence, recognition of expertise, and social connection which surfaced through interviews and reflective discussions aligned with feminist design ethics (Bardzell 2010; Light et al. 2017).

The Triadic Partnership Model

To scale beyond isolated projects, DESIGNwith embedded the Infinity Loop within a triadic partnership model connecting community, academia, and corporations:

- **Community**: contributed lived experience and craft expertise.
- **Academia**: provided research frameworks and reflective evaluation.
- **Corporations**: offered resources and market pathways aligned with ESG goals.

This reciprocal structure ensured that knowledge and value circulated rather than being extracted: corporations advanced authentic sustainability goals, academia generated new insights, and communities gained agency and visibility. The Infinity Loop thus functioned as both a design framework and governance mechanism.

Material Focus: Zero-waste and Textile Revalorization

Grounded in zero-waste principles, the lab sourced offcuts and returned products from Toronto manufacturers. Participants transformed these into functional and narrative-rich artifacts, from bags to picnic mats, linking material circularity with social storytelling. Errors were treated as part of learning, fostering confidence and experimentation. Each product embodied both ecological and cultural value, reinforcing the idea that circular design is also a cultural practice.

Iterative Cycles and Knowledge Mobilization

The methodology unfolded through eight iterative steps of the Infinity Loop, each operationalized through specific workshops and partnerships (see Appendix A): from Decent Employment and Skill Valuation to Zero-Waste Innovation and Re-Seeding Investment. Knowledge was mobilized across platforms (community events, academic presentations, and corporate showcases) ensuring that learning scaled beyond the immediate participants to shape wider systems of practice.

Reflexivity and Ethics

Throughout, the team practiced reflexivity, recognizing their own positionality and power within community contexts (Escobar 2018). Ethical commitments included fair compensation, transparent communication, and shared authorship in exhibitions and publications. Feedback loops with participants continuously shaped project governance, ensuring adaptability and sustained trust.

The Infinity Loop methodology weaves together action research, co-design, feminist ethics, and cross-sector collaboration. By centring marginalized women as co-designers and linking material circularity with social equity, it demonstrates a holistic, replicable approach to systemic innovation, locally in Toronto and beyond.

Case Studies

The DESIGNwith Infinity Loop is not an abstract framework but a lived, iterative process tested across multiple contexts. The following case studies illustrate how the model has been applied and refined through partnerships across cultural, healthcare, and corporate sectors in Toronto. Each demonstrates how the Loop connects employment equity, material circularity, and knowledge mobilization to create scalable systems change.

Case Study 1: The Power Plant Contemporary Art Gallery

Context and Application

As one of DESIGNwith's first institutional partners, The Power Plant offered a platform to test the Infinity Loop as a cultural intervention. Beginning with Step 3: Participatory Design refugee and immigrant women co-created products from discarded exhibition banners, reimagining waste as creative potential. The work culminated in a gallery installation (Step 7: Knowledge Mobilization) where products and stories were exhibited together, reframing textile waste as a site of social and artistic value.

Impact and Lessons

For participants, having their work displayed in a leading art gallery validated their expertise and visibility: "I never imagined my work could be displayed in a gallery. It gave me confidence that my skills are valued here in Canada." For The Power Plant, the collaboration deepened its mandate as a cultural institution, showing that galleries can function as civic agents for circular design. This project underscored how visibility drives legitimacy and future partnerships for community-led sustainability.

Case Study 2: Sinai Health Foundation

Context and Application

Within the healthcare sector, DESIGNwith partnered with Sinai Health Foundation to address textile and promotional waste through Step 4: Zero-Waste Innovation. Immigrant women transformed discarded banners into reusable gift bags for donor events, linking employment equity (Step 1) with corporate ESG alignment (Step 6). Skill-building workshops (Step 2) allowed participants to share textile expertise from their home countries, enriching prototyping processes.

Impact and Lessons

The collaboration provided flexible, dignified work while reconnecting the hospital's own history, founded by four immigrant women, with its present-day sustainability efforts. The project proved how social equity and circular economy goals can intersect, offering Sinai a replicable model for future ESG-driven community engagement.

Case Study 3: CIBC Square

Context and Application

The CIBC Square partnership scaled the Infinity Loop to a large corporate context, activating nearly every step of the model, from employment and skill-sharing to ESG alignment and re-seeding investment. Refugee and immigrant women upcycled massive, perforated vinyl banners from the site's construction fencing into unique commuter bags, storage cubes, and accessories tailored to CIBC Square's brand and tenant needs.

Impact and Lessons

Participants gained creative agency through full design authorship, while CIBC Square employees expressed pride in receiving functional, meaningful products that embodied sustainability and inclusion. The project highlighted the Infinity Loop's scalability, demonstrating how corporate waste streams can become platforms for community empowerment and circular innovation.

Cross-case Analysis

Across these cases, several principles emerged:

- **Visibility drives momentum**: public and institutional showcases build legitimacy and attract new partners.
- **Flexibility sustains engagement**: adapting around participants' cultural and family needs strengthens continuity and trust.

- **Triadic partnerships enable resilience**: academia, corporations, and communities together ensure long-term viability.
- **Circularity is both ecological and social**: transforming waste materials while redistributing opportunity.

Together, these cases affirm the Infinity Loop's core premise: circular economies must be designed as socially as well as environmentally regenerative systems.

Discussion

This discussion assesses the Infinity Loop's contribution to circular economy practice through five dimensions: care, value, systems thinking, co-creation, and real-world impact.

Looking across the case studies, we begin to see how localized interventions, whether repurposing textiles, or revaluing overlooked forms of knowledge, can illuminate broader systemic principles of circularity. While each project was rooted in its specific social and cultural context, together they offer insights into how DESIGNwith's Infinity Loop can be evaluated not only at the micro-scale of community practice but also at the macro-scale of global systems.

By 'zooming out' from these situated experiments, patterns emerge that reveal both the opportunities the Infinity Loop opens, such as building resilience through community co-creation, and the tensions it must navigate, including balancing efficiency with equity or ecological goals with immediate social needs. This section evaluates the model's ability to: embed care as a foundation of circular economies; reframe how value is defined and measured; operationalize systems thinking; sustain initiatives through co-creation; and bridge theory with lived practice.

A key insight across the case studies is that the economy of care (care for people, communities, and the planet) is central to circularity. While mainstream circular economy frameworks often emphasize materials and technological innovation (Ellen MacArthur Foundation 2019), the DESIGNwith projects revealed that systems collapse without sustained attention to social and relational dimensions. Material reuse initiatives succeeded only when local stakeholders were engaged as co-creators, not passive end-users which, when aligned with Raworth's (2017) "doughnut economics", grounds sustainability in human and ecological well-being.

Centring care also reframed design choices. In a textile reuse project, decisions were guided not by efficiency metrics alone but by whether new value chains fostered dignity and empowerment. The implication is that circular economies must integrate both technical and social loops, or inequities persist even as waste is reduced.

Another finding concerns how value itself is defined and measured. Conventional economic systems privilege exchange value (what can be sold or monetized) whereas DESIGNwith's work demonstrates that care, knowledge-sharing, and community resilience are equally vital. In one project, a repair workshop created modest financial revenue but significant social value through intergenerational collaboration. This echoes critiques of capitalist value systems (Graeber 2018), showing that value is culturally situated. By revealing forms of value often overlooked (community trust, shared learning, reduced ecological burden) the Infinity Loop helps rebalance how economies function, ensuring that no single metric dominates.

The case studies also showed how the Infinity Loop surfaces systemic interdependencies. Unlike linear design processes, the Loop is iterative and open-ended, mirroring the feedback loops and complexities of circular economies. It helped connect actors, such as policymakers, waste managers, artists, and residents, revealing 'hidden loops' like informal reuse networks already operating locally. Recognizing and amplifying these dynamics enabled more resilient, adaptive interventions.

This systems-based approach aligns with systemic design (Jones 2014), which advocates designing not just artifacts but relationships, governance, and flows of information. The Loop provided a framework for collective sensemaking and coordination, turning complexity into opportunity.

A further theme is that community co-creation is essential for sustaining circular practices. Many pilots fail due to lack of long-term engagement, whereas DESIGNwith positioned stakeholders as equal partners in defining problems and envisioning futures. In projects, residents contributed practical and cultural knowledge, ensuring solutions were contextually relevant. This participatory approach built ownership and continuity, aligning with humanity-centred design principles (Norman 2018), which emphasize enabling communities rather than designing for them.

Finally, the findings highlight design's role in bridging abstract theory and lived reality. Policy frameworks and economic models provide necessary scaffolding, but it is through material, situated practices that ideas become meaningful. The Infinity Loop turned systemic concepts into actionable steps communities could test and adapt. Rather than resolving tensions between efficiency and equity, or local and global needs, it kept them visible, creating space for negotiation and iteration.

Circular economies, therefore, are not fixed end states but evolving processes. Design's role is not to deliver final solutions but to steward transitions, cultivating the conditions for resilience.

To conclude, DESIGNwith's Infinity Loop offers a valuable contribution to the discourse on circular economies by explicitly integrating care, community, and systemic thinking into design practice. The findings demonstrate that addressing the root causes of the climate crisis and social inequality requires more than technical solutions, it requires redefining value within both design and economic systems. By centring care, amplifying overlooked forms of value, and embedding co-creation, DESIGNwith advances a vision of a circular economy that is environmentally sustainable and socially just. These localized, community-driven interventions scale impact by fostering resilience, equity, and dignity alongside ecological regeneration. Future Loop iterations will focus on quantifying the social and ecological outcomes of these interventions, expanding the model's applicability across diverse cultural contexts.

Ultimately, the health of the planet and the well-being of people are inseparable. When practiced as a facilitator of systemic care, design becomes a powerful tool for navigating this inseparability – bridging theory and practice to cultivate circular economies that honour both ecological boundaries and human needs.

Appendix

Appendix A: Decent Employment and Skill Valuation to Zero-Waste Innovation and Re-Seeding Investment

The Infinity Loop visualizes DESIGNwith's iterative, systemic approach to linking social and ecological regeneration. Structured around eight interconnected steps – (1) Decent Employment, (2) Skill Valuation, (3) Participatory Design, (4) Zero-Waste Innovation, (5) Knowledge Mobilization, (6) ESG Alignment, (7) Re-Seeding Investment, and (8) Systemic Reflection – the Loop operates as both a design and governance model.

Each cycle begins with community engagement and progresses through material experimentation, public dissemination, and reinvestment, ensuring that social and environmental value continuously circulate rather than being extracted. The infinity form underscores that sustainability is not a linear process but a recursive practice of learning, adaptation, and care – one that redefines circular economy as an evolving, humanity-centred system.

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Designing for Circularity: A Systems Approach to Reducing Material Intensity

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Abstract

This paper discusses the role of design in advancing circularity in developed nations by reducing material intensity – the amount of material used per unit of manufacturing value added. It introduces a systemic circular design framework comprising three layers: products, business and service models, and communities and societies. Each layer is illustrated through Australia-based cases: The Reconnect Project (device repair and redistribution), King Living (furniture longevity through services), and Community Gardens Australia (education and advocacy for local food production). The framework maps design activities across these layers, highlighting opportunities for intervention beyond product design – such as reframing human needs and restructuring business and service models. By integrating design and systems thinking, the paper offers a practical approach for identifying the different types of design activities and interventions needed to reduce the material footprint of developed nations while maintaining the quality of living.

Keywords: Circularity, circular economy, material intensity, strategic design, systems thinking.

Introduction

The economic models driving the industrial revolution have led to the depletion of natural resources and excessive waste production (Raworth 2017; Velenturf and Purnell 2021). As a result, as of September 2025, seven of the nine planetary boundaries have been crossed, indicating a high risk of dangerous, irreversible environmental change (Planetary Boundaries Science 2025). A key factor, in terms of the underlying economic models, for this massive-scale environmental degradation has been the linear approach underpinning economic activity. In a linear economy, organizations use natural resources as an input, extracting them from the environment to create materials. Those materials are then turned into products that are either incinerated or thrown away at the end of their life cycle. The steps that a linear economy implements are to take, make, and waste (Baporikar 2020) (see Figure 1).

This approach operates on the assumption that there is an infinite amount of natural resources available as input and that the Earth has an infinite capacity to process landfill and regenerate itself. Value in this model is created through manufacturing and selling products. The aim of an organization operating within this model is to produce as many products as possible and (in many cases) as cheaply as possible. In a linear economy, economic growth is tied directly to resource throughput – how much raw material and energy are used to produce goods and services (Raworth 2017). In developed nations, it is measured primarily through Gross Domestic Product (GDP). Growth in GDP means that more products are being made and sold, regardless of whether they are resource-intensive or waste-generating.

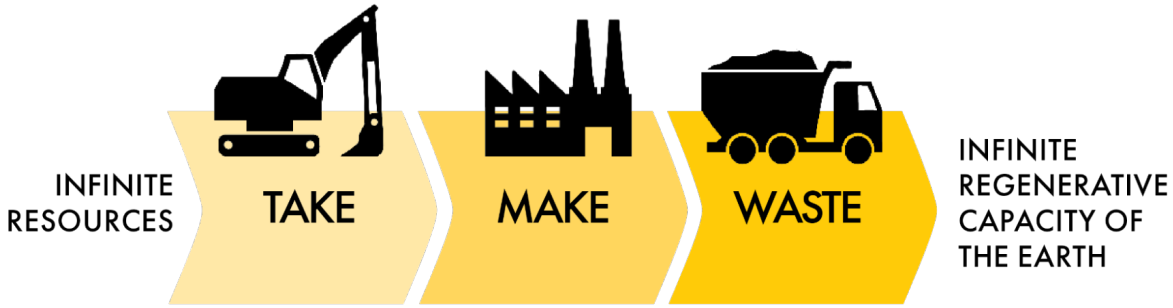

Figure 1: A simplified representation of the linear economy. Credit: Martin Tomitsch and Steve Baty (2023)

To overcome the limitations of the linear economic model, organizations need to move towards circularity (Raworth 2017; Velenturf and Purnell 2021). A circular economy acknowledges that there is a limited amount of natural resources and regenerative capacity available. In a circular model, organizations aim to reduce the resources extracted from the Earth and to limit the amount of landfill and incineration. To achieve this, organizations can use a range of strategies, such as increasing durability, ensuring repairability, allowing for refurbishment, and harvesting used products so that they can be recycled and reused. The challenge is for governments to reduce waste and the depletion of their region's 'common' resources. For organizations, the shift to circular approaches presents an opportunity to transition to sustainable business models and connect with consumers and their shifting expectations (Newman 2020). If implemented at scale, circular models promise to deliver significant financial, social, and environmental benefits (Lewandowski 2016).
Companies that depend on natural resources have begun putting mechanisms in place that will, over time, enable them to shift to circularity (Tomitsch and Baty 2023, 64). For example, IKEA has implemented a 'People and Planet Positive' strategy, which underpins its design decisions (Elmansy 2020). As part of this strategy, IKEA launched a number of long-term goals, such as car-free store concepts, circular design product lines, and a buy-back programme – strategies that span the company's product and business model levels.

In the circular economy, design is the first step of a closed-loop life cycle (see Figure 2). The field of design carries a major responsibility to support and enable the shift to a circular approach (Moreno et al. 2016). Decisions made during this phase will determine not only how products and services will be created, distributed, and used, but also how they will eventually be reused or repaired. Consequently, a large body within the design literature has focused on this challenge, with many studies focusing on the use of sustainable materials and processes when designing products (Van den Berg and Bakker 2015; Moreno et al. 2016). In recent years, this focus has expanded to include service design and business model innovation (Suppipat and Hu 2022).

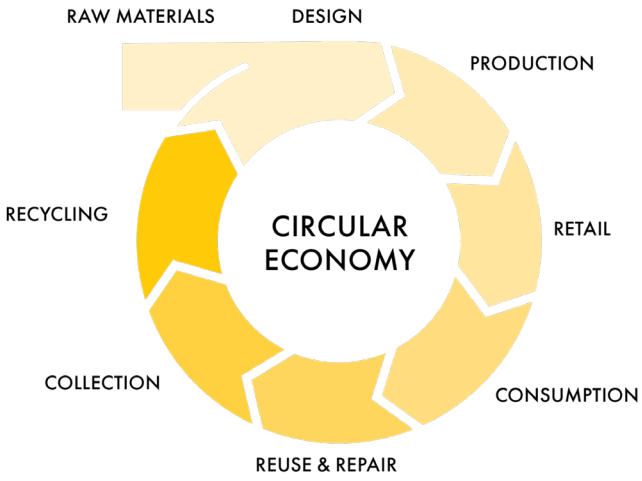

Figure 2: The closed-loop cycle underpinning the circular economy. Credit: Martin Tomitsch and Steve Baty (2023)

Building on these previous studies and drawing on three Australia-based cases, this paper describes a systems approach for identifying opportunities to increase circularity. It introduces a novel perspective through a focus on material intensity – defined as the quantity of material use per unit of manufacturing value added (Upadhyaya, n.d.). In other words, material intensity acts as a measure for how efficiently an economy or sector uses materials to create value. Taking this perspective, the paper goes beyond the traditional focus on reducing material use during the product design and manufacturing stage. It highlights the role of interventions that mediate how products are reused and repaired, the business and service models of organizations, and mechanisms for communities and societies to reduce material intensity by reframing human needs. To guide the practical implementation of this approach, the paper

introduces a triple-layered systemic design framework. The paper discusses how each of these layers can be activated through design activities and proposes the use of strategic design tactics (Tomitsch and Baty 2023), taking a systemic approach to reducing an economy's material intensity. The framework is novel in its systems focus and its ability to cater for sectors such as housing, mobility, food, and utilities, which were identified as the sectors that need to be unlocked to improve Australia's circularity rate (Miatto, Schandl, and Dowse 2024).

Background and Context

Circular Economy and the Waste Hierarchy

In recognition of design's role in shifting from a linear to a circular economy, several design-based frameworks have emerged. Van den Berg and Bakker (2015) developed a circular economy framework from a product design perspective. Their review identified five design-relevant topics: future proof design, design for disassembly, maintenance, remake, and recycling. Moreno et al. (2016) systematically analyzed the 'design for sustainability' literature, linking these approaches to circular business models, and proposed a conceptual framework for circular economy design strategies. Based on their analysis, the authors present a series of recommendations to enable designers to fully consider the holistic implications for design within a circular economy.

Recognizing the limited transferability of existing business models for the circular economy, Lewandowski (2016) conducted a literature review to identify and classify circular economy characteristics. The investigation uncovered two additions to the Business Model Canvas (Osterwalder and Pigneur 2010) components – the take-back system and adoption factors – and a pathway for enabling the transition towards a circular business model.

Other published design frameworks focus on specific material aspects, such as composite materials (Joustra, Flipsen and Balkenende 2021), the user perspective, e.g., designing for circular user behaviours (Wastling, Charnley and Moreno 2018), and sectors, such as the electronics (Suppipat and Hu 2022) industries. Several frameworks have also emerged from design practice and industry, including IDEO's Circular Design Guide (IDEO 2016).

In the European Union, the waste hierarchy, first proposed in 1979, has been influential in setting policy (Zhang et al. 2022). According to an analysis carried out by Zhang et al. (2022), the circular economy and waste hierarchy "share a joint philosophy, aiming to manage waste by rethinking, redesigning, and repurposing in order to improve the resource effectiveness of a product and to reduce the generation and adverse impact of waste". The EU waste hierarchy's layers include prevention, preparing for reuse, recycling, other recovery, and disposal – ordered from the most preferred to least preferred option. Variations of the framework include more detailed descriptors for each layer (Waste Hierarchy, n.d.) (see Figure 3).

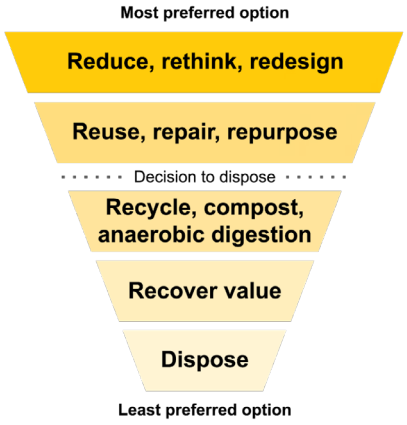

Figure 3: The layers in the waste hierarchy framework (based on Waste Hierarchy n.d.).

The layers in the waste hierarchy, to some extent, align with the objectives of a circular economy, which are: maintenance/longevity, reuse, refurbishment, remanufacture, and recycling (Franconi, Ceschin and Peck 2022). The gap that this paper addresses is the link between these objectives and material intensity as a driver for reducing resource consumption while maintaining the quality of living.

Material Intensity

Material intensity is a concept used in sustainability, industrial ecology, and resource economics to describe the amount of material resources required to produce a given unit of output, such as economic value, energy, or a product (Cleveland and Ruth 1998). It essentially measures the 'weight of the economy' in terms of how dependent it is on physical material inputs (Leigh 2021). The material intensity index of a region is calculated as either the ratio of Domestic Material Consumption (DMC), measured in weight or volume, to GDP (Bithas and Kalimeris 2017).

A lower material intensity indicates higher efficiency – by using less raw material per unit of output. Units of outputs include products and services. Resource use has significantly increased due to increased economic activity, with every 10% rise in GDP in advanced economies resulting in a 6% increase in material footprint (Wiedmann et al. 2015) and total material use tripling at a global level in the past 40 years (Schandl et al. 2018). Global primary materials use is projected to double by 2060 (OECD 2019).

At a macro-economic level, material intensity indicates how resource-intensive an economy is, often linked to discussions of decoupling economic growth from material use (Guo, Cao and Yang 2025). At a product or process level, material intensity allows organizations to measure how much raw material is needed to produce a unit of product or service, such as the amount of steel per car or total materials per smartphone (Upadhyaya, n.d.). At a policy and sustainability level, material intensity provides a key indicator in resource productivity strategies, sustainable development, and achieving a circular economy (Celik, Usman and Alola 2024).

Some studies predict the material intensity of advanced economies to decline over the next decades, as material use is projected to grow at a lower rate than GDP, and due to the growth of the services sector and improved production technologies and processes (OECD 2019). While this may suggest a decoupling of economic growth and material use, a more holistic view rejects this projection (Wiedmann et al. 2015; Parrique et al. 2019; Bithas and Kalimeris 2017).

In this paper, we focus on material-intensive sectors, which include construction, basic metals, energy supply, agriculture, and manufacturing (OECD 2019). These sectors can be mapped to human needs, such as housing, transport/mobility, energy, food, and goods (e.g., electronic consumer products, clothing, etc.). They also align with the sectors that need to be unlocked to improve Australia's circularity rate – housing, mobility, food, and utilities (Miatto, Schandl and Dowse 2024).

In practical terms, material intensity for housing, for example, can be reduced through building fewer homes, housing with a smaller footprint, using regenerative or fewer materials, and retrofitting. The material intensity of electronic consumer products can be reduced through designing more durable and longer-lasting devices and making it easier to refurbish and repair products – strategies that align with circular objectives.

Systems Thinking

To investigate the link between circular objectives and material intensity, it is necessary to take a systems perspective – zooming out from the product to understanding the larger ecosystem within which products are situated. Systems thinking, as an approach, offers a way to consider all the components of a system and systems within systems, in order to find the relationships and interactions between them (Wiener 1956; Senge and Sterman 1992; Meadows 2008).

Buchanan (2007) positions systems as the fourth order in design, focusing on designing environments and ecosystems (see Figure 4). Design on this level becomes an organizing act (Tomitsch and Baty 2023). Instead of creating a physical product or a digital website, design is used to manipulate, transform, and organize components, including an organization's culture and values. By taking this approach, the framework presented in this paper goes beyond a product and service focus, taking into account the broader systems that affect and are affected when considering circular objectives and material intensity.

Circularity and Material Intensity in the Australian Context

Australia's circularity rate – defined as the "measure of efficiency in which resources are reused and recycled within a system" – is 4.4% (Australian Bureau of Statistics 2024). In comparison, Europe's circularity rate sits at 11.8% (EEA, n.d.), and the global average is 6.9% (Circle Economy 2025). These figures suggest an untapped potential to improve Australia's circularity through targeted interventions. A study calculated Australia's theoretical capacity to be as high as 32%, highlighting the need to "rethink how we use materials, from designing products that use less material to schemes that extend the lifetime of products" (Miatto, Schandl, and Dowse 2024).

The success of Australia's transition to a circular economy requires intervention at multiple points in the product lifecycle; within organizations and the way they are structured; and across the economy. These interventions acknowledge the systemic nature of the economy when it comes to the circular economy, and sit within an overall framework that targets actions at different conceptual levels, from economy-wide policy and regulation, all the way through to individual product design decisions.

Australia is one of the world's most material-intensive countries, with its material extraction sitting at 93.3 tons per capita in 2017 – over two-and-a-half times more than Canada and almost four times China's per capita rate (IRP 2019). It is also the world's largest net exporter of materials measured by the Physical Trade Balance (PTB) (IRP 2019). Connected to human needs, Australia has a high rate of personal car ownership (Currie, Delbosc, and Pavková 2018) and the largest average floor area of a new dwelling in the world (Crawford et al. 2025) – further adding to its material footprint.

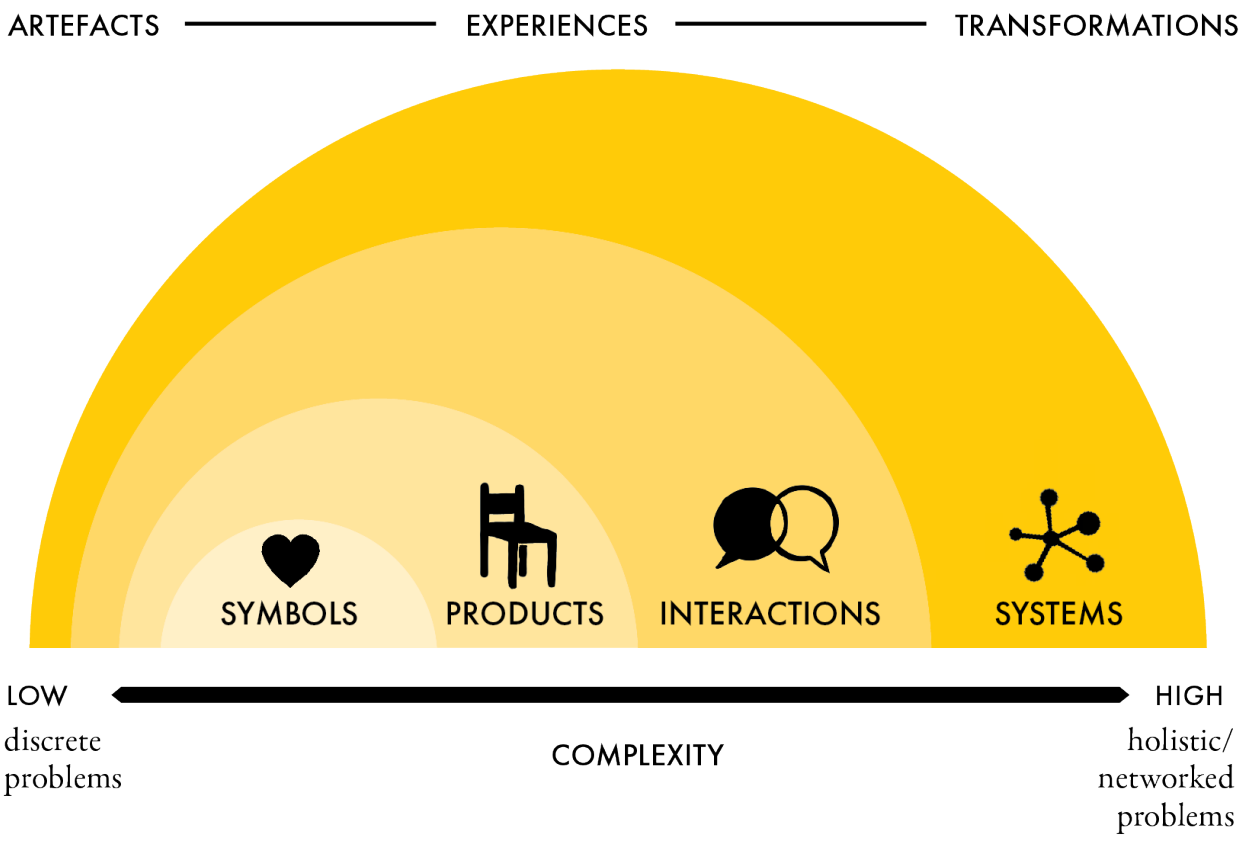

Figure 4: The evolution of design practice from symbols, products, and interactions to systems. Credit: Martin Tomitsch and Steve Baty (based on Buchanan 2001)

Methodology

Using Australia as the context, the framework presented in this paper was developed through a generative approach involving three steps:

1. An initial model was conceptualized through bringing together the first author's experience of engaging with circularity in practice and previous literature on circularity, material intensity, and systems thinking.

2. We then applied the framework to three Australia-based cases, which we selected to represent different types of products and initiatives. For the case analysis, we drew on publicly available information about the businesses behind the selected cases, primarily from their public websites. This led us to refine the layers, focusing more specifically on the aspect of material intensity and how each layer can be activated to reduce material intensity.

3. We subsequently contrasted the framework and its layers with other circularity frameworks published in the literature, and discuss similarities and differences in the Discussion section.

The following section presents the framework and its layers. The subsequent section provides a description of the selected case studies and discusses the framework and how its layers are addressed in the cases.

The Triple-layered Systemic Design Framework

The systemic circular design framework comprises three layers (see Figure 5):

Products: the model's bottom layer focuses on improving the reuse and repairability of products to keep them in use for longer. Specific to Australia, the NSW Environmental Protection Authority has highlighted the role of reuse and repair in a discussion paper on a circular economy approach for the state of New South Wales (EPA 2018). This tier covers product-level design decisions such as choice of materials, designing for easy disassembly, the use of glues, toxic materials, lubricants, and the like, modularity, and standardization.

Business and service models: the middle layer is concerned with designing models to encourage reuse and repair, and grow second-hand markets, reducing the volume of goods that end up in landfill and providing services to extend the lifetime of products. This tier involves creating business models that allow for circular practices to exist within enterprises, and the service models needed to support them.

Communities and societies: the top layer argues for a reframing of human needs and solving them in ways that are inherently less materially intensive, which includes a change of conceptual frame away from individualism toward shared ownership and collective resource use. Interventions and activities in this tier include policy and regulatory settings, government incentives and disincentives, import/export controls, and large-scale consumer behaviours and attitudes.

The following subsections describe each layer along with examples for interventions and activities in more detail, starting with the top layer – communities and societies – to demonstrate the interconnected nature of the layers, and how decisions and interventions made at the top layer filter down to the other layers.

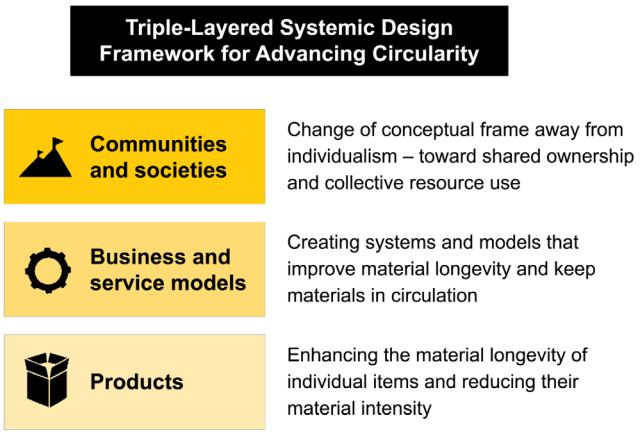

Figure 5: The three layers of the systemic design framework.

Communities and Societal Change
At this first level, government intervention is necessary and can come in a number of forms:

- Legislating a right to repair, which includes the availability of spare parts, diagnostic tools, and warranty protections (among other features) to force product manufacturers to ensure consumers can have their product repaired by a repairer of their choice.
- Legislating for product disclosures, in the form of a digital product passport, for example, that include measures of product repairability and durability.
- Incentivizing the development of new products – e.g. through Australia's existing R&D tax credit scheme that meet minimum benchmarks for repairability and durability, and disincentivizing the development of new products that are difficult to repair, single-use, or disposable.
- Introducing procurement processes across the different tiers of government (federal, state, local) that weigh in favour of products that have higher repairability and durability indices.
- Encouraging the take-up of trade and technical apprenticeships to increase the available pool of qualified repair technicians, currently well below the levels Australia needs in order to meet its future circularity goals.

The challenge with the introduction of these measures is that businesses are not currently able to service the volumes of repair requests, deliver spare parts to a wide variety of repair outlets, or manufacture products effectively that can be easily disassembled and repaired. This is addressed in the second tier: business and service models.

Business and Service Models
Very few businesses are structured in a manner that encourages product repair over the long term. With rare exceptions, business models tend to support short product lifespans with regular upgrades and planned obsolescence.

In recent years, companies have become increasingly protective of their intellectual property when it comes to the internal workings of their products, resulting in black box components that are more likely to be swapped out whole, proprietary diagnostic tools needed to identify operational issues, and a dearth of third-party components.

Service models, similarly, favour replacement over repair. It is increasingly difficult to get some classes of product repaired in a cost-effective manner, resulting in more and more products that could still be used finding their way to landfill.

Local councils, faced with unbearable pressure on landfill, are undertaking work to identify alternative approaches. Recent work by the Australian Product Stewardship Centre of Excellence, UTS Institute of Sustainable Futures, and RPS Consulting for the Southern Sydney Regional Organization of Councils exploring product stewardship for whitegoods is a good example of these efforts (Gertsakis et al. 2025). One of the report's recommendations is the introduction of eco-modulated fees to encourage design for circularity features. This has the potential to influence business and service model considerations at the level of individual manufacturers.

Consumers need to be able to reliably find qualified repairers capable of diagnosing an issue with a product, sourcing genuine spare parts, and carrying out repairs, in a manner that is time and cost-effective for the consumer, and convenient for both drop-off and pick-up of the item (either by the repairer or the consumer). Failure to do so could lead to future hesitancy to head down a repair path, undermining transition efforts.

Similarly, the perceived value of repaired and refurbished products needs to shift. Second-hand markets for many product categories (with the exception of used vehicles and, more recently, clothing) remain small. Opportunities for businesses to operate in these spaces within the economy – as dedicated repair centres, refurbishers, and resellers – remain limited by consumer demand, manufacturer practices, and the availability of repair technicians.

Product Design

Product-level efforts to improve repairability are perhaps the most obvious to reduce material intensity and increase circularity. Yet they remain held back by systemic issues, such that manufacturers are loath to give up profit in the absence of government intervention, and consumers are ill-equipped to make product purchasing decisions on the basis of repairability in the absence of product disclosure information on these product characteristics.

The experience of individuals attempting to repair items today further creates obstacles for this transition. The first author's recent experience highlights the negative reinforcement of repair that comes from a poor repair experience. A kitchen appliance – a mixer that retails for around AUD 1,000 – was recently put out of commission. Finding a technician able to diagnose the problem for that type of appliance was a challenge, with the closest service provider being a 20-minute drive away. Upon dropping off the appliance, the provider took nearly two weeks to undertake the diagnosis, and the cost of repair was estimated to be about 80% of the replacement cost. Unsurprisingly, the provider advised against proceeding.

This anecdotal experience has also been observed in studies on consumers' repair experiences (Huang, Esmaeilian, and Behdad 2016). The consistently low price of new products remains a key barrier for consumers seeking out repair options. This is exacerbated by the poor quality of products, which not only reduces their lifespan but also results in low profitability in repair work for businesses (Laitala et al. 2021).

Reducing material intensity and keeping materials out of landfill relies on product-level design decisions aimed at improving the durability and repairability of individual products. These are well-known and align with broader circular objectives: designing for disassembly, choosing more durable, recyclable, and renewable materials; reducing the reliance on electronics, embedded batteries, plastics, and glues; and designing for modularity and an open parts ecosystem. This is not an exhaustive list, but it provides a good indication of the direction needed in product design.

As with any systemic design transition, a right to repair will require intervention at multiple points of the economy, in a sequenced and coordinated manner. At the level of the economy, the federal government signaling the introduction of legislation with a fixed timeline for the transition will create the regulatory environment needed to kick-start action at other tiers. In the absence of that driver, market forces will continue to incentivize non-circular behaviours amongst businesses and consumers.

Case Study Analysis

We selected three cases from the Australian context to demonstrate the framework and its layers. The cases were chosen to represent a diverse range of products and initiatives. In selecting the cases, we also looked for examples that address the layers of the model in different ways and to different extents. This allows for a discussion of strengths and opportunities as well as gaps that the framework is able to reveal.

The Reconnect Project

The Reconnect Project[1], an initiative that repairs phones, tablets, and laptops for distribution to women and children affected by domestic violence, youths who are unhoused and at-risk, refugees, and others in need (see Image 1). This case primarily operates at the middle layer, with some interaction with the bottom layer. It would benefit from initiatives at the top level, such as a government incentivized programme to refurbish and reuse electronic consumer devices. The NSW EPA discussion paper (EPA 2018) makes a start by proposing the value of repair in a circular economy, but this is still lacking in practice within the Australian context.

The middle layer is implemented through a business and service model innovation, collecting devices and delivering them to people in need, and offering training and career opportunities for neurodivergent young adults with practical skills in mobile phone repair, retail operations, and customer service.

Since The Reconnect Project collects and processes previously used electronic consumer products, it does not directly engage in any product-level interventions. However, using the model uncovers some opportunities for how interventions at that level would benefit the case; for example, if manufacturers of those devices would provide a repairability index or make repair information more readily available, this would benefit The Reconnect Project's service model. This, in turn, requires intervention at the top level, with the European Extended Producer Responsibility (EPR) framework being a good example for a government-led policy by shifting the burden of waste management from public authorities to producers, thus incentivizing them to design more sustainable and recyclable products (OECD 2024).

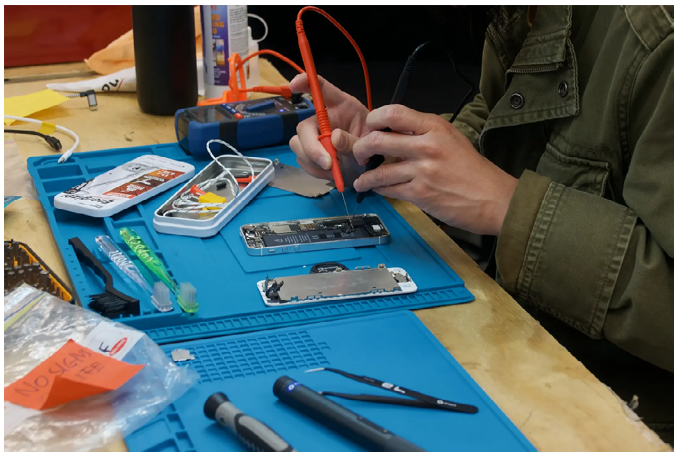

Image 1: The Reconnect Project collects used phones, tablets, and laptops to give them a second life, and provides a repair training programme for young neurodivergent adults. Credit: The Reconnect Project

1 https://thereconnectproject.com.agovernment-incentivisedu

King Living

King Living[2] is an Australian furniture business that takes "a conservative approach to growth" by reducing the volume of furniture that ends up in landfill and providing services to extend the lifetime of its products, such as in-home cleaning (see Image 2). This case primarily operates across the bottom and middle layers. At the product level, the company controls design, manufacture, and retail, which enables it to have control over material and process decisions. Its furniture design preferences timeless, low-trend aesthetics over fast-fashion trends to encourage longer usage. The company's sofas have tailored removable covers so fabrics can be cleaned, replaced, or renewed rather than discarding the whole sofa.

The furniture's frames are made from high-grade galvanized steel, which is infinitely recyclable. This enables King Living to provide a 25-year warranty on its steel frames, addressing the middle layer in terms of the company's service model. It also offers an aftercare service to refurbish or re-cover existing furniture, which contributes to extending its life.

This case would likewise further benefit from government-led policy setting at the top layer, incentivizing companies like King Living to invest in high-quality, durable materials and service models that extend the lifespan of products. Without intervention at this layer, King Living's positioning as a premium brand may limit accessibility for consumers, meaning their influence is more niche compared to mass-market furniture.

Image 2: King Living provides durable furniture and repair and refurbish services – allowing consumers to turn their old (left) into a new sofa (right). Credit: King Living

Community Gardens Australia

Community Gardens Australia (CGA)[3] supports and advocates for community gardening activities, reducing dependence on an extended food system that is both energy intensive (transport, fertilizer, refrigeration, etc.) and wasteful (spoilage, rejection by retailers and customers, etc.) (see Image 3). Its vision is to create connected, nourishing, accessible, and resilient community gardens for all Australians.

Because CGA is not a manufacturing company but a community and advocacy network organization, many of its material intensity contributions are indirect or systemic. For example, by providing access to locally grown food, this reduces material use associated with the agriculture sector, which is one of the most carbon-intensive sectors in Australia.

CGA operates across all three layers. At the top layer, they advocate to local governments and institutions to support community gardening. CGA also works with local councils to influence policy on urban gardening. Its service model – the middle layer of the framework – includes offering education and resources to support people and communities to start or maintain gardens. In terms of the business model, CGA relies on volunteers and membership fees. Their intention is to seek government funding, which comes back to the top layer, requiring governments to offer funding schemes that incentivize locally grown food over mass production. At the bottom layer sits the produce – localized food production and shortening supply chains.

Image 3: Community Garden Australia is an advocacy group. Credit: Community Garden Australia

Discussion and Future Opportunities

The power of design is working within the constraints – how to deliver the same quality of living but use less. Design provides the capability to rethink how to meet that quality of living (e.g., no car-dependent suburbs that do not have local services, using coal to produce electricity, burning petrol to drive cars). This involves looking at actors (e.g., the company designing smartphones versus an initiative like The Reconnect Project) on each layer as acting independently since they have no influence across levels. Systems thinking contributes an important perspective as it provides leverage points for where and how to intervene (Meadows 2008). Systems dynamics cuts across the layers, which are effectively scales in society.

Specific design activities lend themselves to fulfilling the aims of each of the layers. Design activities on the top layer include strategic design, systems design, and policy design, to some extent, also urban planning, as it is concerned with macro and policy questions. These activities need to be conducted with a view to global initiatives and government-wide strategies, for example, to promote and advance circular approaches on a government level. Design activities at the middle layer include business model innovation, design innovation, and service design. At this tier, design can be used, for example, to demonstrate how repairability plays out from a business consideration. Design activities at the bottom layer include product innovation, product design, industrial design, architecture, and also service design. These are the more traditional design activities, focusing on second and third orders in Buchanan's (2007) model.

We acknowledge that this is a somewhat simplified and generalized account of the multiplicity of design as an evolving field and that some of these activities may be overlapping or converging in practice. However, we hope that this discussion provides a starting point for further evolution – and critique – of the framework and how it can be activated through design in practice. There are further untapped opportunities for a deeper exploration of the role of strategic design tactics (Tomitsch and Baty 2023) in addressing circular objectives and reducing material intensity across the three layers of the model. In particular, strategic design is useful to understand and drive change at the top tier of the framework due to its focus on networks, interventions, and partnerships (see Figure 6) – key pillars when it comes to driving systemic change at a societal level.

2 https://www.kingliving.com.au
3 https://communitygarden.org.au

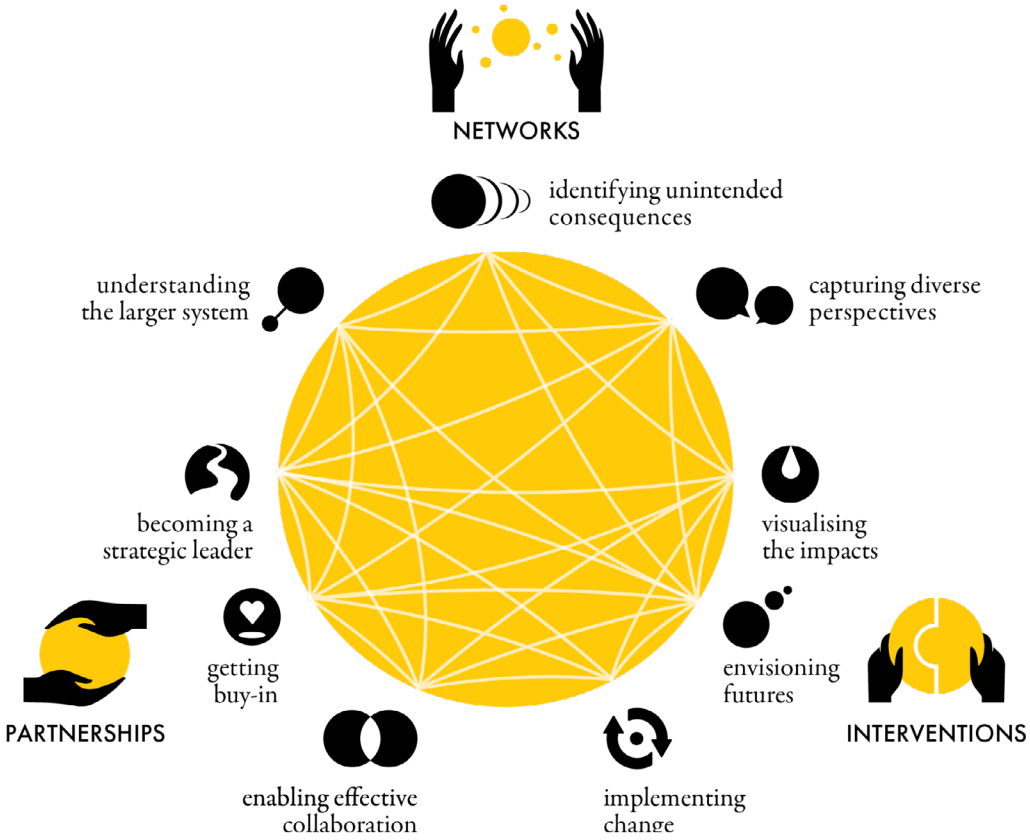

Figure 6: Nine interconnected strategic design tactics that are able to cut across the three layers of the framework for driving systemic change with the aim of reducing material intensity. Credit: Martin Tomitsch and Steve Baty (2023)

A review by Franconi et al. (2022) found that the current literature emphasizes business and product-related initiatives. By proposing a multi-hierarchical framework, they aim to shift the focus to long-term value creation. Our framework contributes to this shift by extending the perspective from product and business and service models to changing the frame toward shared ownership and collective resource use. The approach of sharing resources, such as tools, and how design can contribute to enabling such models has received significant attention in the literature (Dillahunt et al. 2017; Fedosov, Albano, and Langheinrich 2018; Jones et al. 2023), also referred to as the 'sharing economy' (Stephany 2015). The novel conceptual contribution that our framework makes is, first, linking shared ownership with the material intensity perspective and circular objectives. Second, the framework presents shared ownership as a separate layer to emphasize the focus on long-term value creation for communities and societies.

Unlike other frameworks, the systemic design framework presented in this paper includes the necessary high-level step of reframing the way we approach meeting fundamental human needs – such as housing, transport/mobility, energy, food – towards a conceptualization that is more inherently low in material intensity. Furthermore, the framework focuses on the specific role of systemic design to reduce material intensity in a comprehensive manner, rather than identifying broad mechanisms such as those presented in the Waste Hierarchy framework (Zhang et al. 2022).

The paper argues for a shift in how designers consider and make choices about which materials to use (Karana *et al.* 2012) to a 'material intensity' view. Notably, this is not limited to the design of physical products and environments but extends to interaction (Fernaeus and Sundström 2012; Wiberg 2014) and service design (Blomkvist, Clatworthy, and Holmlid 2016; Penin 2018), bridging what has been described as the world–representation gap (Wiberg 2018, 4). Applying a material intensity view expands design as an activity from creating products, environments, interactions, and services to understanding and influencing systems.

A key aspect of material intensity as a measure is its ability to capture how efficiently an economy or sector uses materials to create value. However, how 'value' is defined is an important consideration that requires further work within the context of the proposed systemic design framework. Again, it may be useful to draw on established notions and movements within the field of design, such as value-sensitive design (Friedman 1996) or life-centred design (Borthwick, Tomitsch, and Gaughwin 2022; Lutz 2022). More work is needed to link these concepts with economic concepts, and emerging movements that argue against GDP as a measure of productivity or a nation's prosperity (Schepelmann, Goossens, and Makipaa 2009).

As the framework was developed within the Australian context, further work is also required to consider its applicability to other nations. However, given Australia's status as an advanced economy, we argue that the framework applies at least in similar ways to other developed nations.

Conclusion

Moving the global economy back within the sustainable zone of planetary boundaries requires a major reduction in the material intensity of developed nations. A large body of work from fields such as economics and sustainable development has contributed studies, analyses, and reports on the role of material use and the links between material intensity and sustainability. However, within the field of design, the concept of material intensity has received little attention beyond the consideration of material use in product design and production processes. Strategic design – as a methodology for bringing systems thinking into design – has a significant role to play when it comes to realizing a truly regenerative circular economy, as reducing the material intensity of existing solutions to fundamental human needs will not go far enough.

This paper discussed shifting towards conceptual framings of fundamental human needs that are more inherently sustainable and of lower material intensity. The triple-layered systemic design framework provides a structured approach to working through the necessary changes at multiple levels of problem-solving. How to deliver those changes and interventions in ways that are less material-intensive requires systems conversations and a participatory approach to policy making that brings together consumers, the private sector, and the government.

The aim of the triple-layered systemic design framework is to create a conceptual foundation for this work, and to further investigate the links between reducing material intensity while ensuring a safe and just future for all (Lambertini et al. 2025) alongside practical questions, such as how to design environments and objects inside environments so they can be taken apart, repaired, refurbished, and actively reused.

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Economies of Enough: Designing Circularity from Grassroots in India's Craft Sector

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Abstract

As the climate crisis accelerates, this paper introduces *Economies of Enough*; design-led models of production that privilege ecological balance, cultural continuity, and livelihood security over extractive growth. Grounded in the everyday practices and design of craft-based businesses in India, it examines how creative manufacturing systems operationalize circularity through locally rooted, resource-efficient, and community-driven approaches. Case studies – from waste-to-wealth textile innovation to regenerative dyeing – demonstrate how design mediates between tradition and transformation, translating tacit knowledge into regenerative practice. By situating design within everyday acts of making, the paper challenges dominant narratives that frame circularity as a high-tech, industry-led endeavour. Instead, it positions frugality, repair, and continuity as critical forms of design intelligence, revealing how the future of circular design emerges through plural, care-based, and culturally embedded modes of production in the Global South.

Keywords: Circular economy, creative industries, design innovation, economies of enough, Indigenous knowledge, informal economies, resource efficiency, waste minimization.

Introduction

As the climate crisis intensifies and socio-economic inequalities deepen, the urgency for alternative economic paradigms has become increasingly pressing. India, home to the world's largest informal economy, stands at the forefront of this challenge. In 2025, the country ranked sixth on the Global Climate Risk Index, having experienced more than four hundred extreme weather events since 1993. These have resulted in economic losses of approximately USD 180 billion and at least eighty thousand fatalities (Germanwatch 2025). Such crises disproportionately affect marginalized populations: women and children are fourteen times more likely to die than men during climate disasters, reflecting entrenched social inequalities, limited access to information, and constrained mobility (UN Women 2023). Nearly 28% of India's craft workforce belongs to Scheduled Castes, Scheduled Tribes, and Other Backward Classes, groups historically excluded from formal socio-economic opportunities (NSSO 2019). At the same time, 56% of artisans in India are women, highlighting the intersection of gender, labour, and resilience in the country's creative sectors (Development Commissioner [Handicrafts] 2022).

India's informal economy, which constitutes nearly 80% of its workforce, plays a vital role in both social and ecological resilience (ILO 2018). Within this context, the crafts sector emerges as a pivotal actor. Beyond preserving rich cultural heritage, it supports livelihoods, sustains local ecologies, and contributes meaningfully to 12 of the 17 United Nations Sustainable Development Goals (UNDP 2020). Many artisans are also engaged in agriculture, creating intrinsic linkages between rural livelihoods, material cycles, and craft production. Yet, despite its scale and impact, the sector is often overlooked in mainstream economic and circularity discourse. Low-technology, labour-intensive practices that underpin traditional crafts risk being marginalized in favour of industrial, high-technology solutions that dominate global circular economy frameworks (Schröder et al. 2022).

Image 1: India's informal economy, which constitutes nearly 80% of its workforce, plays a vital role in both social and ecological resilience. Credit: Annie Spratt

Against this backdrop, the concept of *Economies of Enough* offers a socially grounded, Global South–rooted perspective on circularity. As articulated by Diane Coyle (2011), the *Economics of Enough* challenges conventional models of perpetual growth and advocates for economic systems that prioritize well-being, sustainability, and equity over gross domestic product (GDP). Coyle's framework calls for a redefinition of prosperity to include environmental stewardship, social capital, and intergenerational responsibility. When translated into the context of craft economies, this approach foregrounds sufficiency, mindful resource use, and care for both communities and ecosystems as the cornerstones of a sustainable future.

Craft-based enterprises in India actively embody this ethos of enough. They design and produce with locally available materials, integrate circular and eco-friendly processes, and embed technology selectively to enhance, rather than replace, traditional knowledge systems. Their hybrid supply chains combining decentralized local production with selective central coordination reflect a distributed model of economic resilience rooted in social and ecological balance. By prioritizing livelihood security, interdependence, and community well-being over scale and accumulation, these enterprises operationalize the principles Coyle identifies as necessary for a post-growth economy. In particular, women artisans' lived realities – shaped by mobility constraints, caregiving responsibilities, and socio-cultural norms inform modes of production that value time, reciprocity, and care, rather than efficiency alone. These practices illustrate how circularity, when grounded in local ethics of sufficiency and inclusion, moves beyond industrial recycling logic to a broader framework of economic and social regeneration.

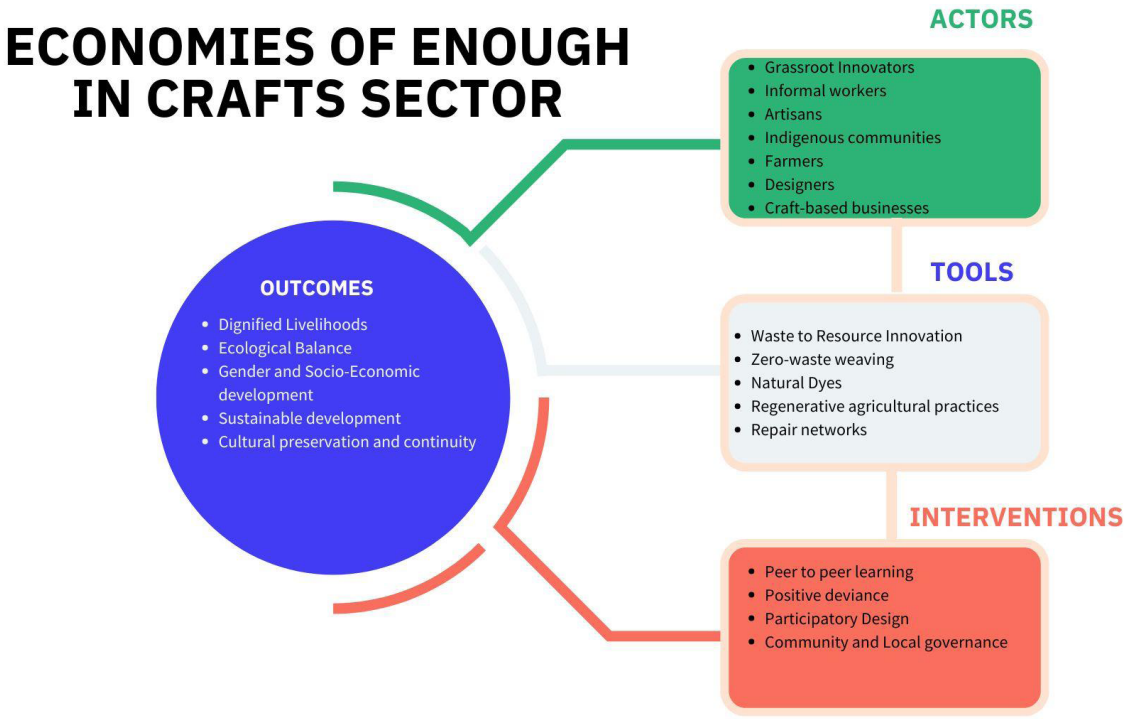

Figure 1: Illustrative framework depicting the interconnections between actors, tools, and interventions that collectively enable outcomes aligned with the principles of *Economies of Enough* within India's craft sector.

This paper examines how grassroots craft-based enterprises in India enact circularity through actors, tools, and interventions, focusing on women artisans, informal workers, community organizations, and local designers. It explores the mechanisms through which these stakeholders integrate low-impact materials, zero-waste techniques, regenerative practices, and knowledge-sharing networks to sustain livelihoods while minimizing ecological footprints. By documenting these models, the paper seeks to answer three interconnected questions:

1. How do craft-based enterprises in India embody circularity in practice?
2. What actors, tools, and interventions make these practices possible?
3. How might these grassroots approaches inform circularity in other contexts, particularly in Global South economies?

In addressing these questions, this study reframes circularity not merely as a technical or industrial challenge but as a social, ecological, and culturally embedded practice. It positions India's craft sector as a living laboratory of sufficiency-driven design, where low-technology, community-led innovation demonstrates the potential for sustainable, equitable, and resilient economies. By foregrounding the experiences and strategies of artisans and other informal actors, this research offers both conceptual insights and practical guidance for scaling circularity from grassroots to global contexts.

Literature Review: Circularity Beyond Industrial Frameworks

Conversations on the circular economy often begin with industrial strategies such as recycling plastics, designing factories to minimize waste, or extending product lifespans. While these frameworks are significant, they are typically oriented towards corporations and governments, assuming access to infrastructure, technology, and scale (Stahel 2016; Ellen MacArthur Foundation 2019). This focus, however, frequently overlooks the world's largest workforce of circular practitioners: informal workers, artisans, farmers, and small enterprises, particularly in the Global South (ILO 2018; Goyal 2021).

Scholars have increasingly emphasized that circularity is not solely a technological challenge but also a social and organizational one. Raworth's (2017) *Doughnut Economics* frames economies as needing to operate within two boundaries: a social foundation, where human needs are met, and an ecological ceiling, where planetary limits are respected. Within this "safe and just space", small-scale, community-driven economies such as craft find a natural fit. Manzini (2015) extends this with the notion of "small, local, open and connected" design, in which communities produce what they need, exchange knowledge openly, and remain rooted in place while linked to broader networks. Similarly, Thackara (2019) proposes the *100-Mile Economy* framework, highlighting how local production and consumption cycles can reduce dependency, strengthen resilience, and build reciprocal ties between communities and ecosystems.

These perspectives resonate with the functioning of informal economies, where production and exchange are often governed by trust, reciprocity, and collective decision-making rather than formal market mechanisms (Gudeman 2001). In India, nearly 80% of the workforce is informally employed, with little formal recognition but deeply embedded systems of skill and resilience (ILO 2018). Within this, creative manufacturing, or craft – such as weaving, pottery, embroidery, basketry, and metalwork – plays a crucial role. These practices rely on tacit knowledge: skills transmitted through observation, apprenticeship, and embodied practice rather than codified instruction (Goyal 2021).

Tacit knowledge is especially important for sustaining circular systems. For example, a weaver repairing a loom with spare wood, a dyer intuitively sensing the right moment to remove yarn from an indigo vat, or a potter judging clay quality by touch all demonstrate how embodied expertise enables continuity with minimal external inputs (Sennett 2008). Such skills are difficult to formalize but are vital for resilient livelihoods and low-impact production.

The framework of "positive deviance" provides another useful lens. It highlights how some communities already solve shared problems using the same resources available to others, but through unique practices (Marsh et al. 2004). In craft clusters, for instance, some artisans have innovated with waste silk and cotton threads to create marketable products, while others have built peer networks to negotiate fairer prices. Rather than imposing external models, identifying and amplifying these positive outliers can help scale context-sensitive solutions.

Indigenous and local governance systems in South Asia further illustrate how circular practices are embedded in social structures. In Meghalaya, village communities maintain cleanliness without municipal contracts, while Dorbar Shnong (Khasi councils) regulate commons and resolve disputes. Naga Hoho assemblies provide a collective voice for fragmented tribal groups. Historically, Indian srenis (guilds) regulated craft quality, worker welfare, and material flows, serving as early institutional models of circularity (Chattopadhyaya 1975). These examples underscore that community-driven governance has long provided mechanisms of resource management and social regulation aligned with circular principles.

Transition studies contribute an anticipatory dimension, calling for co-created knowledge that enables communities to imagine and build their own futures (Geels 2002; Avelino and Wittmayer 2016). In craft contexts, this translates into experiments with "enoughness." For instance, businesses such as Golden Feathers reimagine waste as raw material; Adivpure blends natural dyes derived from flower waste with contemporary design in Mumbai; and women's collectives such as Maati Community establish local seed banks in remote interiors of Assam. These examples illustrate how circular innovation is not confined to laboratories but thrives in low-technology handlooms, dye pits, and design workshops, where sufficiency-driven production is intertwined with livelihoods, culture, and ecology.

This context points to several insights:

1. The circular economy is not monolithic: while industrial solutions dominate discourse, grassroots practices, particularly in India's craft sector embody sufficiency-driven, community-led circularity (Stahel 2016; Raworth 2017).
2. Tacit knowledge, though often undervalued, is critical to maintaining resilient craft systems (Goyal 2021; Sennett 2008).
3. Positive deviance provides a practical method for identifying and amplifying successful grassroots solutions (Marsh et al. 2004).
4. Local and historical institutions from guilds to village councils offer governance structures aligned with circular principles (Chattopadhyaya 1975). Finally, design and transition scholarship emphasizes a systems approach that integrates empathy and structural awareness, enabling people-centred yet ecologically grounded interventions (Manzini 2015; SSIR 2018).

What remains underexplored is structured evidence of how specific actors (artisans, designers, NGOs, micro-entrepreneurs, women's collectives), tools (waste-to-resource innovations, zero-waste weaving, natural dyeing, repair networks), and interventions come together in practice, and what lessons they offer for global circular economy debates. This study addresses that gap by positioning India's craft sector as a laboratory for *Economies of Enough*, following Diane Coyle's framework, where production is not about maximizing outputs but about creatively sustaining a balance between culture, livelihoods, and ecology. By linking tacit knowledge, positive deviance, and local governance to sufficiency-driven circularity, the paper demonstrates how grassroots craft economies operationalize principles of well-being, ecological stewardship, and equity, offering a Global South perspective often missing from dominant industrial narratives.

Methodology

This study adopts a qualitative, multi-method approach to explore India's informal craft economies, prioritizing contextual depth and co-created insights. This approach captures tacit knowledge, embedded practices, and relational systems often overlooked by quantitative methods (Goyal 2021; Sennett 2008). Four craft-based enterprises were selected for their rootedness in traditional artisanal knowledge, circularity practices — such as waste-to-resource innovations, regenerative techniques, and thread banks — and diverse organizational models.

Data collection combined semi-structured interviews, case studies, and enterprise mapping through the data provided by the enterprises for the Kula Innovate Challenge applications. Interviews featured key stakeholders, capturing multiple perspectives within each enterprise. Each enterprise was documented as a case study, examining its origins, structure, market engagement, and circular practices. Actor mapping visualized how knowledge, materials, and value flow between primary actors (artisans, designers, entrepreneurs) and secondary actors.

The study specifically analyzed tools and interventions such as upcycling, natural dyeing, zero-waste weaving, and local repair networks. These practices are interpreted through the lens of *Economies of Enough*, emphasizing sufficiency, community-centred production, and ecological balance rather than maximization (Coyle 2011).

This qualitative design is justified by its sensitivity to socio-economic and cultural realities of the Global South, its capacity to foreground marginalized actors, and its rigour through triangulation of interviews, observation, and documentation. Collectively, these methods provide a nuanced understanding of how circularity is practiced and sustained in informal craft economies (Stake 1995; Yin 2018; Goyal 2021).

Decolonizing Circularity: Reframing India's Craft Sector as an *Economy of Enough*

Mainstream circular economy frameworks, largely designed in industrialized contexts, tend to emphasize metrics, technological efficiency, and scalability (Ellen MacArthur Foundation 2013). Such models often overlook informal and tacitly organized economies, where innovation is relational, iterative, and deeply embedded in local contexts (Bhaduri 2022). In contrast, India's craft sector operates within a decentralized new formal economy sustained by trust, reciprocity, and social capital — challenging rigid boundaries between economic, social, and ecological systems (Business of Handmade 2021).

Recent scholarship calls for decolonizing circularity by recognizing Indigenous and craft-based systems as living laboratories of sustainability (Chikarmane 2021; Reddy 2022). This reframing shifts attention from top-down, standardized interventions to community-driven approaches that privilege sufficiency, care, and ecological stewardship over extraction and accumulation. Within this lens, the idea of *Economies of Enough* (Coyle 2021) challenges dominant growth paradigms by foregrounding production and consumption systems based on restraint, well-being, and interdependence.

India's craft sector employing nearly 200 million people across diverse geographies, embodies these ethics through material sensitivity, creative ingenuity, and localized sustainability (Business of Handmade 2021). Artisans practice sufficiency by prioritizing quality over quantity, repair over replacement, and local sourcing over global supply chains. Craft-based enterprises illustrate advanced forms of circularity through techniques such as natural dyeing, upcycling, and zero-waste

weaving. For instance, Adivpure transforms temple flower waste into plant-based dyes, reducing synthetic chemical use, while zero-waste weaving clusters demonstrate precision and resource efficiency rooted in traditional knowledge.

These practices reveal the craft sector's inherent circularity — where value is regenerated through community knowledge, ecological awareness, and distributed production. However, despite its ecological and social strengths, the sector faces significant structural challenges: limited access to global markets, insufficient infrastructure and capital, policy inconsistencies, and the dual threats of imitation and cultural appropriation. Such conditions weaken artisanal resilience and highlight the need for context-aware policy and financing frameworks that recognize the distinct logic of handmade economies.

Conventional measurement tools focused on carbon footprints or productivity, fail to capture the relational, qualitative dimensions that sustain circular craft systems (Singhal 2023). Metrics designed for industrial economies rarely account for social continuity, interdependence, and ecological balance. Emerging South Asian initiatives such as *Business of Handmade* are beginning to document these embedded forms of circularity, calling for context-sensitive evaluation models aligned with informal, community-based production.

Building on this growing body of work, the present study explores how artisans and creative entrepreneurs in India articulate, measure, and sustain circularity from within their lived contexts. It frames circularity not as an external design intervention but as a *social practice* embedded in local worldviews, materials, and relationships. Through qualitative case studies and participatory research, the study illuminates how informal craft systems operationalize sufficiency, repair, and shared value offering critical insights for reimagining sustainable economies from the ground up.

Case Studies: Operationalizing *Economies of Enough*

The four case studies illustrate how India's craft-based and creative manufacturing enterprises operationalize *Economies of Enough* through context-specific, sufficiency-driven models. Each responds uniquely to the challenges of ecological degradation, industrial overproduction, and precarious livelihoods. From material-led circular innovation to cooperative exchange systems and impact-led fashion, these cases show how local embeddedness, cultural continuity, and social equity can drive regenerative value creation. Collectively, they reveal plural vocabularies of sustainability arising from India's informal and creative economies; where circularity is not merely technical, but deeply relational and community-driven.

Case 1: Golden Feathers

Image 2: From chicken feather waste to fabric. Credit: Golden Feathers

Location: Jaipur, Rajasthan
Founder: Radhesh Agrahari, Abhishek Verma and Muskan Sainik
Established: 2019
Artisans: ~200 (85% women)
Organization: For-profit and Non-profit (B2B2C)

Golden Feathers pioneers sustainable innovation by transforming butchery chicken waste into a natural woollen fibre through a 27-stage chemical-free sanitization process. This material innovation replaces tree-based paper and synthetic fibres while addressing waste management challenges. Each year, the enterprise converts 57 000 kilograms of feathers into biodegradable fibre, reducing its carbon footprint by 7.7 billion kilograms of CO_2 equivalent.

Operating through decentralized, low-tech systems, Golden Feathers engages semi-skilled and unskilled women artisans in handloom and handmade paper production, aligning ecological regeneration with livelihood creation. Its model exemplifies sufficiency by producing within natural limits rather than scaling industrially.

Image 3: Golden Feathers' Rajesh Agrahari training rural artisans and weavers. Credit: Golden Feathers

The enterprise has directly impacted over 2000 women, providing dignified, skill-based employment and incomes up to twenty times higher than regional averages. By upskilling 375 workers and developing eco-friendly product categories, Golden Feathers demonstrates how waste-to-value innovation can balance economic, ecological, and social objectives — illustrating sufficiency as both environmental restraint and social empowerment.

Case 2: Xuta – The Thread Bank

Image 4: Xuta addresses liquidity barriers faced by handloom weavers through India's first yarn bank. Credit: Xuta

Location: Majuli, Assam
Founder: Pabitra Lamah Samrah and Rishi raj Sarmah
Established: 2012
Artisans: ~500 (90% women)
Organization: For-profit (B2B)

Xuta, founded under Maati Community's long-term engagement addresses liquidity barriers faced by handloom weavers through India's first yarn bank. Situated in Majuli, the world's largest river island, it provides yarn loans to weavers, replacing exploitative credit systems with trust-based, community-led lending.

Image 5: Xuta secures livelihoods for over 500 women artisans, transforming them from wage earners to stakeholders. Credit: Xuta

Operating on bamboo looms without electricity, Xuta integrates wild silk, natural dyes, and zero-waste weaving. Regenerative dye sources are cultivated locally, closing material loops and reinforcing ecological rhythms. Transparent documentation ensures artisans' ownership and fair compensation.

The initiative secures livelihoods for over 500 women artisans, transforming them from wage earners to stakeholders. It advances ecological regeneration through sustainable silk rearing and natural dye cultivation, reinforcing social security and collective confidence. Xuta exemplifies sufficiency-led circularity by linking local resource cycles with equitable community governance; proving that relational economies can substitute extractive financial systems within craft value chains.

Case 3: Projecthrive by Sonica Sarna Design

Image 6: Sonica Sarna Design integrates sustainability science with craft-based production across twelve Indian states. Credit: Sonica Sarna

Location: New Delhi
Founder: Sonica Sarna
Established: 2016
Artisans: ~800 (60% women)
Organization: For-profit (B2B)

Sonica Sarna Design integrates sustainability science with craft-based production across 12 Indian states. Through its initiatives — Sonica Sarna Design and Projecthrive — it builds transparent, ethical supply chains linking Indian artisans to global fashion brands. Its reporting systems measure impact across carbon, water, and waste metrics, positioning impact as a new indicator of value beyond profit or scale.

Image 7: Sonica Sarna's artisan partners for crochet-based design and production done for Marrow Anam. Credit: Sonica Sarna

The enterprise embeds regenerative materials, fair wages, and women's empowerment within its supply chains, redefining circularity as both social and institutional transformation. Global clients such as Crate & Barrel and Christy Dawn adopt its transparency frameworks, aligning brand ethics with measurable sustainability.

By ensuring artisans participate in decision-making and receive long-term equitable contracts, the enterprise connects grassroots resilience with global accountability. Sonica Sarna Design demonstrates how economies of enough can operate within transnational markets — advancing sufficiency through care, transparency, and redistributive business ethics that decouple growth from extraction.

Case 4: Biodye

Image 8: Natural dye herbs, fruits and flowers from India. Credit: Biodye

Location: Nashik, Maharashtra
Founders: Bosco Henriques & Mustafa Motiwalla
Established: ~2016
Artisans: 18
Organization: Social enterprise (B2B)

Biodye bridges scientific research with traditional dyeing practices to revive India's natural dye ecosystem. Sourcing chromogenic dye plants from the Western Ghats, it employs sustainable harvesting; collecting only one-third of each plant and re-harvesting every three years — thereby coupling production with forest regeneration.

Using closed-loop water systems, non-toxic mordants, and solid-waste composting, Biodye embodies ecological sufficiency. Its dyes, developed through nine years of research, are long-lasting, machine-washable, and provide ultraviolet and odour-resistant properties, proving that natural systems can meet modern performance standards.

Socially, Biodye generates dignified employment for tribal artisans and rural women collectors. Many artisans have become supervisors, investing in education and local enterprises. Environmentally, its replanting initiatives have expanded regional green cover, transforming degraded lands into productive ecosystems.

By merging scientific precision with indigenous knowledge, Biodye exemplifies sufficiency as ecological and social regeneration — illustrating a replicable Global South model for circular design rooted in respect for natural limits and community well-being.

Image 9: Artisan partners at Biodye showcasing freshly indigo dyed t-shirts (left). Farmer showcasing freshly harvested indigo plants (right). Credit: Biodye

Synthesis and Comparative Insights

Case	Actors	Tools / Interventions	Key Outcomes	Transferability Potential	Notes / Constraints
Golden Feathers	Artisans, designers, weavers, technical experts.	Chicken feather waste to paper, fabric and yarns.	Waste reduction, dignified livelihoods for marginalized women.	High: applicable to other livestock waste.	Requires local waste collection systems and capacity building.
Xuta/Maati Community	Social impact leaders, community leaders, weavers, natural dyers.	Thread bank to ensure consistent supply of high-quality yarn to women weavers.	Dignified livelihoods, Income generation, traditional and regenerative practices continuation.	Medium: similar seed and thread bank can be established for other natural materials in naturally rich geographies.	Needs context specific seeds, threads and understanding of local agroecology.
Project Thrive	Social enterprises, designers, cooperatives, artisans.	Context specific, impact measurement and evaluation.	Funding access, holistic impact measurement rooted in the South Asian realities and sustainable practices.	High: co-designed metrics adaptable in other geographies.	Needs data literacy and access to technology.
Biodye	Farmers, social enterprises, designers, cooperatives, artisans.	Regenerative agriculture, traditional knowledge systems embedded with contemporary practices for natural dyes.	Toxin free, less water intensive natural dyeing, soil regeneration, ecological restoration, new skills to the local community.	Medium: Transferable in only naturally rich geographies.	Consistent market demand necessary.

Table 1: A table synthesizing and comparing the four case studies.

Across these four cases, shared values of sufficiency, interdependence, and ecological care emerge as counterpoints to dominant models of industrial circularity. Collectively, these enterprises show that *Economies of Enough* are dynamic systems in which production, care, and regeneration reinforce one another. They position India's craft and creative manufacturing sectors as laboratories of plural, sufficiency-driven futures that redefine what sustainability can mean in the Global South.

Designing Systems of Enough: A Framework for Craft-led Circularity

To synthesize the insights from the case studies, this section presents a design-centric framework that captures how 'enoughness' manifests in practice. The framework is organized around four interlinked pillars: resource efficiency, cultural sustainability, economic inclusion, and alternative impact measurement, which together form a model of sufficiency-driven circularity. Each pillar represents a design dimension through which craft-based enterprises operationalize balance rather than growth, showing that regenerative economies can be both socially embedded and ecologically grounded.

Defining the Four Pillars

Pillar	Definition
Resource Efficiency and Regeneration	Designing systems that reduce waste and optimize locally available resources through reuse, repair, and upcycling. Efficiency here is not about maximizing throughput but achieving equilibrium between ecological capacity and livelihood needs (Stahel 2016; Raworth 2017).
Cultural Sustainability	Preserving and renewing traditional craft knowledge, local materials, and community identity as regenerative resources. Sustainability thus becomes epistemic — anchored in cultural memory and ecological reciprocity (Manzini 2015; Thackara 2019).
Economic Inclusion	Structuring production around equity, shared ownership, and collective agency. Inclusion redefines the circular economy as a social system of cooperation and care rather than a technocratic mechanism (Avelino and Wittmayer 2016).
Alternative Impact Measurement	Developing participatory tools that capture social, cultural, and ecological value invisible to standard economic metrics, turning measurement itself into a co-design process (Coyle 2011).

Table 2: Definitions of the four pillars of the *Economies of Enough* framework.

Design Framework Overview

Pillar	Key Actors	Core Tools/ Interventions	Key Outcomes	Systemic Impact
Resource Efficiency and Regeneration	Artisans, eco-technicians, farmers' cooperatives, local governments.	Regenerative dye cycles (Biodye); waste-to-value fibre processes (Golden Feathers); local sourcing of renewable materials; water recycling and composting systems.	Economic: new income streams from resource recovery and renewable sourcing. Ecological: soil restoration, reforestation, and waste reduction. Social: training of artisans and rural women in sustainable production.	Reframes production as ecological repair, transforming craft into a regenerative, bioregional economy aligned with the economies of enough ethos.
Cultural Sustainability	Rural farmers, indigenous weavers, women artisans, NGOs.	Seed preservation and agro-ecological textile systems (Xuta, Maati Thread Bank); intergenerational training and cultural archiving.	Economic: stable fibre supply chains and long-term livelihood security. Ecological: biodiversity protection through indigenous farming. Cultural: continuity of local design vocabularies and community identity.	Anchors sustainability in cultural knowledge, where traditional techniques function as regenerative design systems.
Economic Inclusion	Women-led collectives, micro-entrepreneurs, social enterprises.	Cooperative circular models; community reinvestment systems; gender-equitable training and market linkages.	Economic: collective risk-sharing, fair pricing, and stable earnings. Social: empowerment of women and marginalized artisans. Ecological: shared monitoring of sustainable material use.	Converts circularity into a socially embedded system prioritizing livelihood sufficiency and collective agency over profit maximization.
Alternative Impact Measurement	Social enterprises, data facilitators, impact investors, design collectives.	Co-designed dashboards (Projecthrive); participatory evaluation; visual storytelling and community reporting.	Economic: enhanced access to ethical finance and responsible markets. Ecological: accountability for emissions and resource use. Social: recognition of artisans' contribution to impact creation.	Recasts measurement as an inclusive design process, enabling informal economies to define success through care and reciprocity.

Table 3: Design-centric framework: actors, tools, outcomes, and systemic impacts.

Interlinkages Across Pillars: The Sufficiency Loop

These four pillars function not in isolation but as a mutually reinforcing system.

- **Resource efficiency and regeneration** supports **economic inclusion** by lowering production costs and enabling shared infrastructure.
- **Cultural sustainability** enriches **impact measurement** by embedding qualitative indicators such as intergenerational knowledge transfer and community well-being.
- **Economic inclusion** in turn strengthens **resource efficiency**, ensuring fair access to ecological benefits.

Together, they form a **Sufficiency Loop** – a cyclical design model that balances production and consumption within ecological and social thresholds (Raworth 2017; Coyle 2011). Unlike growth-oriented circular models, the sufficiency loop prioritizes regeneration, reciprocity, and equilibrium rather than throughput or expansion.

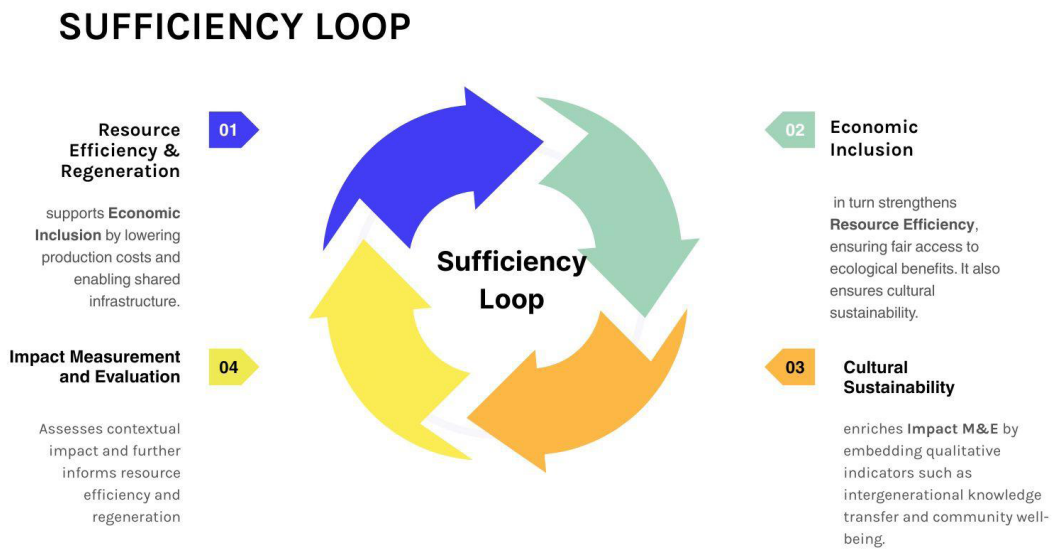

Figure 2: The Sufficiency Loop Framework showcases the interconnections between the four pillars of Resource Efficiency, Cultural Sustainability, Economic Inclusion, and Alternative Impact Measurement.

Transferability and Adaptation

While each enterprise operates in a distinct context, the framework's principles are transferable through design, not replication. The following synthesis identifies cross-case elements that can guide adaptation elsewhere in the Global South. While rooted in distinct local contexts, these models share transferable design principles that can inform sustainable development in other Global South economies.

The framework's strength lies in its adaptability to local socio-ecological contexts, building trust, redistributing agency, and embedding sustainability within communities. Sufficiency becomes a creative condition rather than a constraint, as India's craft economies reimagine design, production, and evaluation within ecological limits. By integrating resource efficiency, cultural sustainability, economic inclusion, and alternative impact measurement, these *Economies of Enough* offer scalable, context-sensitive models grounded in care, reciprocity, and everyday design intelligence.

Transferable Element	Origin Case	Adaptation Conditions	Potential Application
Natural dye and regenerative agricultural practices	Biodye	Availability of natural flora and resources, rural labour networks.	Bioregional dyeing and natural pigment economies in tropical zones.
Waste-to-value material innovation	Golden Feathers	Local organic waste and basic processing infrastructure.	-
Agro-ecological integration	Xuta / Maati Seed Bank	Fibre-linked agriculture and access to community land.	Textile-farming systems combining agriculture and craft.
Co-designed impact metrics	Projecthrive	Local trust networks and transparent leadership.	Contextual ESG frameworks for informal creative economies.

Table 4: Transferable design elements and adaptation pathways.

Structural Inhibitors to Economies of Enough

While case studies show pathways for embedding *Economies of Enough* in India's craft and informal sectors, structural and infrastructural constraints limit their scale, visibility, and recognition. These arise from how the craft economy is positioned within development, policy, and innovation frameworks.

1. Visibility and Access to Capital
Craft enterprises following sufficiency principles often remain invisible to investors, policymakers, and impact measurement systems due to their small scale and informal supply chains (ILO 2018; UNCTAD 2020). As a result, these models risk being undervalued for prioritizing social and ecological well-being over rapid growth, relying instead on short-term grants rather than patient, long-term capital.

2. Infrastructure Limitations
Resource-efficient production is constrained by inadequate infrastructure. Rural craft clusters often lack clean water, renewable energy, and waste processing facilities needed for localized material loops (GIZ 2022). Existing innovations frequently operate in isolation, dependent on small artisan networks. Without decentralized facilities such as community dyeing units or repair centres, circular production struggles to scale.

3. Policy Gaps
The craft sector spans culture, agriculture, and small-scale industry, yet policy frameworks remain fragmented across ministries (Ministry of MSME 2020). Innovation funds and sustainability programmes often target formal enterprises or tech-led startups, leaving community-led and producer owned initiatives like waste-to-yarn projects outside mainstream R&D (NITI Aayog 2021). Tailored regulations for non-traditional materials are largely absent, imposing compliance burdens on small producers.

4. Tradition vs Market Demands
Engaging contemporary markets creates tension between preserving traditional techniques and meeting standardized delivery and compliance expectations. Rapid scaling risks diluting craftsmanship, while small-batch authenticity can constrain income growth (Sinha & Mehra 2022). Balancing cultural and ecological integrity with economic viability requires careful negotiation.

5. Methodological Limitations
Assessing the impact of economies of enough is challenging. Conventional sustainability indicators often fail to capture qualitative outcomes such as community well-being, ecological reciprocity, or intergenerational knowledge transfer (Berkes 2018). Data scarcity and inconsistent documentation limit rigorous evaluation. New frameworks are needed to measure social and ecological value that reflect the relational logic of craft economies.

These constraints reveal a paradox: the very features that make craft-based circular systems sustainable – localization, informality, and sufficiency – also marginalize them within dominant policy, market, and compliance frameworks. Addressing these blind spots is essential for systemic transformation.

Conclusion

India's informal craft sector offers a compelling model for sustainable development through the lens of *Economies of Enough*. Artisanal and community-based enterprises operationalize principles of sufficiency, relational prosperity, and ecological stewardship, challenging dominant growth-oriented paradigms (Banerjee 2022; Chatterjee 2020). By embedding circularity within local materials, knowledge systems, and social networks, these enterprises illustrate that sustainability is not merely a technical or industrial challenge but a social and cultural practice (Dhar 2025; Yadav et al. 2022).To translate these insights into actionable strategies, stakeholders across policy, design, finance, education, and research should consider the following:

Policy: Incentivize Circular Craft Enterprises and Reward Community-Led Innovation

- Offer fiscal incentives for enterprises using locally sourced, regenerative, or waste-derived materials (Khan 2022).
- Promote innovation challenges and community-led design experiments combining traditional skills with sustainability outcomes.
- Integrate craft into rural development programmes as a pillar of green livelihoods and climate resilience, moving beyond heritage preservation to active low-carbon innovation.

Design Interventions: Establish Design Labs and Support Local Material Loops

- Co-create regional design labs enabling collaboration among artisans, designers, and engineers on low-impact materials and processes. Develop open-source toolkits for waste valorization and natural dyeing. Facilitate peer-to-peer learning and serve as local testing grounds for repair, reuse, and remanufacturing models.

Investment: Deploy Patient Capital for Grassroots Initiatives

- Provide long-term, low-interest loans and blended finance tailored to sufficiency-oriented enterprises. Encourage community-based equity models where artisans hold stakes in cooperatives
- Launch green/social impact bonds and sustainability-linked credit lines for small producers practicing circularity.

Education: Embed Global South Perspectives in Design and Management Curricula

- Integrate craft-based design, indigenous ecological knowledge, and sufficiency ethics into core curricula. Promote interdisciplinary teaching connecting design, ecology, and development studies, emphasizing case-based learning from grassroots innovations.

Knowledge Sharing: Scale Learnings to Other Contexts

- Create open-access repositories documenting successful community-based circular models.
- Host inter-regional residencies and policy dialogues linking craft ecosystems across South Asia, Africa, and Latin America. Encourage South–South collaborations that exchange practical frameworks rather than top-down technical assistance.

Evidence Building and Research: Strengthen Measurement of Social and Environmental Impact

- Conduct longitudinal studies tracking economic, ecological, and social outcomes of craft-based circular initiatives. Develop standardized yet context-sensitive indicators capturing qualitative dimensions such as community well-being, knowledge transfer, and cultural continuity.
- Facilitate collaborative research networks linking universities, NGOs, and artisan cooperatives to co-produce actionable insights. Promote open-access publications translating research findings into evidence for funding, policy, and market recognition.

By foregrounding these strategies, policymakers, designers, financiers, and educators can create enabling environments that scale *Economies of Enough* beyond individual communities. Informal craft economies, long marginalized in economic discourse, offer critical alternatives to growth-driven paradigms. Their emphasis on sufficiency, reciprocity, and ecological balance provides a guiding framework for post-growth, socially inclusive, and culturally grounded sustainable development.

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Orchestrating Circular Economic Transition in Rural China through Design Innovation: Creative Village Practice and Viability

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Abstract

This research examines how design innovation drives rural circular economic transformation through the Farewell to Cambridge project in Wawu Village (China), which transformed abandoned dwellings into a creative complex integrating guesthouses, galleries, and community facilities. Through qualitative case study methods, this study develops a four-dimensional circular design framework: material circulation, functional transformation, cultural regeneration, and community co-creation. Findings reveal that designers function as 'circular system integrators', coordinating mutually reinforcing dimensions that form self-sustaining closed-loop systems. Four transferable principles emerge: adaptive resource integration, multi-dimensional synergistic innovation, multi-party value coordination, and cultural-economic fusion. This research extends circular design from industrial to rural contexts, expands circulation beyond material to encompass functional, cultural, and social dimensions, and redefines designers' roles as system integrators rather than technical problem-solvers, providing a systematic framework for sustainable rural transformation.

Keywords: Circular economy, community co-creation, design innovation, rural revitalization, system integration.

1. Introduction

1.1. Context

Traditional villages in China face the challenge of "hollowing out" (Liu et al. 2009, 2016; Dai & Yi 2015): abandonment of old dwellings (architectural hollowing), decline of traditional agriculture (industrial hollowing), and out-migration of young adults (demographic hollowing). These issues have led to the deterioration of rural physical space, economic development, and community vitality. The integration of agriculture, culture, and tourism represents a crucial initiative for China's rural revitalization strategy. However, traditional approaches often perpetuate the linear 'take-make-dispose' economic model: demolishing abandoned dwellings generates construction waste, new buildings consume large quantities of virgin materials, and homogenized, commodified cultural symbols proliferate. This has resulted in resource waste, cultural discontinuity, and ecological pressures in rural development (Ghisellini et al. 2016).

The circular economy offers a new paradigm for rural development transformation. Its essence lies in repositioning waste as resources and maximizing value through closed-loop systems (Lu and Chen 2014). In rural transformation practices, this means re-examining abandoned architectural spaces, traditional craftsmanship, and cultural heritage, where design innovation can play a pivotal role in converting these elements into valuable resources.

In recent years, design practices in China's rural revitalization have become increasingly diverse, encompassing spatial renovation, product innovation, and community participation. Duan (2023) notes that as an emerging practice, rural design requires designers to transcend traditional disciplinary boundaries and adopt holistic thinking to provide comprehensive solutions for rural development. Design is no longer merely a technical tool but a systemic force integrating economic, ecological, and cultural dimensions to achieve sustainable, resilient, and valuable rural circular development. However, questions remain regarding how design can advance circular economy implementation in rural contexts and coordinate multiple objectives across economic, ecological, and cultural dimensions.

1.2. Research Gap

Current research on circular design applications in rural contexts remains insufficient, with existing literature primarily focusing on manufacturing and urban environments (Ghisellini et al. 2016). Additionally, the role of design and designers in circular economy transitions lacks clarity. Existing design research tends to focus on single-dimensional technical solutions while overlooking the innovative potential of design as a systemic integration tool.

1.3. Research Aims and Questions

Through the case of the Farewell to Cambridge Art Gallery Guesthouse project in Wawu Village (China) (see Image 1), which transformed abandoned traditional dwellings into a creative complex integrating guesthouses, galleries, and art installations, this research explores how design innovation drives rural circular economic transition.

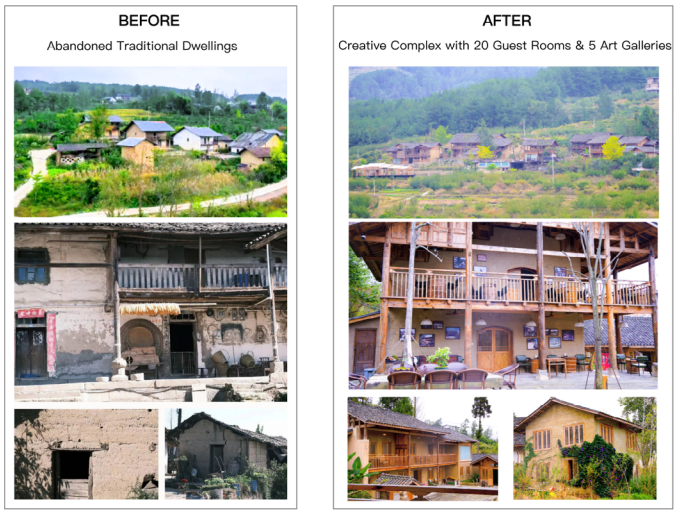

Image 1: The Wawu Village transformation, from abandoned dwellings to creative complexes. Credit: Farewell to Cambridge Project

The study focuses on three questions: First, how does circular design address sustainability challenges in rural development? Second, what roles do designers and circular design play in this process? Third, what value and scalability potential does this design practice demonstrate?

2. Research Design

2.1. Circular Economy Principles and Levels

The circular economy is "an industrial economy that is restorative by intention and aims to rely on renewable energy; minimises, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design" (Ellen MacArthur Foundation 2013). The UNEP Finance Initiative explicitly defines core circular economy principles: eliminate waste and pollution, circulate products and materials at their highest value, and regenerate natural resources. It categorizes practices into three levels: first, smarter product use and manufacturing; second, extending product and component lifecycles; third, material applications.

McDonough and Braungart's (2002) 'Cradle to Cradle' philosophy emphasizes that design should eliminate the concept of waste from the outset. Circular design, as a practical methodology of circular economy, refers to the systematic application of circular economy principles at every design stage, ensuring products, spaces, and systems circulate at their highest value (Ellen MacArthur Foundation 2013).

However, as the three-level framework primarily addresses industrial product circulation, this research constructs a theoretical framework from four dimensions tailored to rural development specificities:

1. **Material circulation**: restoration and reuse of materials and resources.
2. **Functional transformation**: multi-functional conversion and adaptive design of spaces.
3. **Cultural regeneration**: preservation and renewal of traditional culture.
4. **Community co-creation**: local resident empowerment and benefit sharing.

2.2. Case Study: Farewell to Cambridge Project, Wawu Village

Farewell to Cambridge project is located in Wawu Village, Qiaotou Town, Shizhu Tujia Autonomous County, Chongqing (China), at an average elevation of nearly 900 metres. Despite its rich natural resources and cultural heritage, the sparse population and mountainous terrain limit industrial development opportunities.

Image 2: Aerial view of the Farewell to Cambridge Art Gallery guesthouse project.
Credit: Farewell to Cambridge Project

The project encompasses approximately 5000㎡ and adopts a systematic design approach of art and rural courtyards, transforming seven abandoned traditional dwellings into a creative complex. The layout includes 20 hotel rooms, five themed art galleries, and nine art installations (see Image 2). The architectural design primarily retains the original wooden mortise-and-tenon structure while functionally updating the traditional architectural fabric. Operationally, it integrates commercial formats such as Yunran Bookstore, Qingshi Agricultural Products, and Rural Academy. This enables Farewell to Cambridge to transition from a single guesthouse to a leisure guesthouse cluster and ultimately toward a rural community, exploring a new model of art and rural courtyards.

The case selection is based on typicality, innovation, and accessibility. Wawu Village is a key village for rural revitalization support in Chongqing, exemplifying the development challenges and transformation needs facing traditional villages. The project integrates spatial renovation, format diversification, and community services in systematic design, demonstrating circular economy principles in design practice.

2.3. Data Collection and Analysis

This research employs qualitative research methods, focusing on the Farewell to Cambridge design project in Wawu Village to explore how design innovation drives rural circular economic transition.

Research data was collected through multiple sources:

1. Documentary materials: collection of project-related planning documents, design specifications, and news reports to trace project background, development trajectory, and social impact.
2. Field investigations: the research team conducted on-site investigations in April 2025, recording architectural renovation details, material usage, spatial layouts, and operational conditions through participatory observation, including photographs and videos.
3. In-depth interviews and semi-structured interviews with core stakeholders, including:
   - Designers: exploring circular design philosophies, strategies, and applications.
   - Operators: understanding business models, operations, and revenue conditions.
   - Local villagers: examining community participation, benefit-sharing mechanisms, and identity.
   - Officials: understanding development planning, policy support, and project processes.

Data analysis employed mixed methods including the thematic analysis (Braun & Clarke 2006) of textual materials to identify design practices related to the analytical dimensions as well as the comparative analysis of visual materials (photographs, design drawings) to interpret circular design principles and practical logic.

3. Findings: Design for Circular Transition

Through the Farewell to Cambridge design project, this research reveals how designers function as circular system integrators, coordinating four-dimensional design practices — material, functional, cultural, and community — to drive transformation from abandoned dwellings to creative complexes. First, designers demonstrate four roles as circular system integrators; second, circular design drives the circular system through four dimensions, generating synergistic effects; third, circular transformation creates multi-dimensional value, from which transferable design principles are distilled.

3.1. Designers as Circular System Integrators

Designers function as circular system integrators coordinating rural circular economic transition. Unlike traditional single-dimensional technical interventions, designers demonstrate systematic problem-solving capabilities, integrating technical, cultural, and social dimensions, embodying four roles as integrators:

1. **Circular system architects**: orchestrate overall renovation, breaking from traditional guesthouse room-ratio design logic to configure guest rooms, galleries, and art installations, constructing an architecture of material, functional, cultural, and community circulation.
2. **Cultural translators**: innovate traditional forms into contemporary expressions, realizing innovation in knowledge and craftsmanship, translating traditional culture into contemporary architectural and cultural language.
3. **Community catalysts**: implement manager training, enhancing villagers' skills. Art galleries open freely with regular training sessions, forming participatory co-creation models.
4. **Innovation drivers**: incubate agricultural product brands, designing commercial pathways from adoption to vegetable banquets, innovating art value conversion models where exhibits (cultural value) become tearoom supplies (functional value) and commercial products (economic value).

Multi-role capabilities enable designers to practice circular systems through holistic rather than fragmented systematic approaches.

3.2. Four-dimensional Circular Design Practice

Circular design drives the transformation of Wawu Village from abandoned dwellings to a creative complex through systematic interventions across four dimensions: material, functional, cultural, and community (see Image 2). These four dimensions do not operate independently but form a mutually nested and reinforcing circular system: material circulation establishes the physical foundation, enabling abandoned buildings to regain vitality; functional transformation breaks through single-use limitations, creating composite value spaces; cultural renewal transforms traditional resources into contemporary cultural capital; community co-creation ensures the sustainability and social inclusiveness of the transformation. The following sections elaborate on the specific practices and circular mechanisms of each dimension.

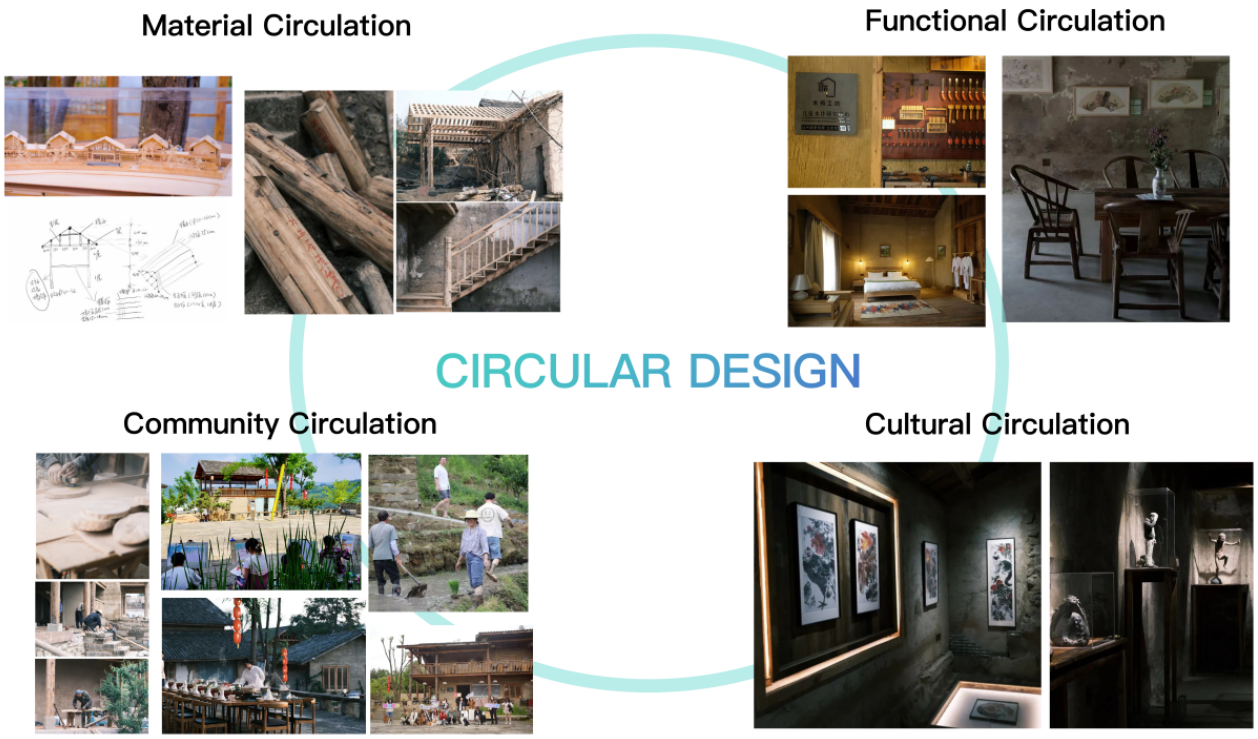

Image 2: Four-dimensional Circular Economy Innovation Framework Driven by Design.

3.2.1. Material Circulation: Preserving and Reusing Traditional Building Materials

The project preserved the original mortise-and-tenon wooden structural framework of traditional dwellings. Design documentation states that "we did not want to simply demolish and rebuild." Architectural restoration followed traditional 'Eight Great Crafts' techniques, adopting a systematic material strategy of 'wood as skeleton, earth and stone as body, tiles as covering', engaging local craftsmen with traditional skills in restoration work, achieving inheritance of both physical materials and craft knowledge (Image 3).

Material circulation embodies inner-circle principles. Blue tiles, old timber, and rammed earth walls, originally considered construction waste, were reintegrated into new spaces through design, achieving transformation from ruins to valuable spaces. This restoration strategy avoided costs of construction waste disposal and new material procurement. More importantly, the authentic historical character created by original materials brings higher cultural premium to the project, which new construction cannot achieve.

Image 3: Material circulation.

3.2.2. Functional Transformation: From Dwelling to Creative Complex

Functional transformation demonstrates how the project achieved transition from single residential function to multi-functional complex through spatial reconstruction.

The project transformed abandoned dwellings into multifunctional spaces integrating accommodation, exhibition, retail, and education (see Image 4). Breaking from traditional guesthouse room efficiency design logic, it dramatically adjusted public-to-guest room ratios from conventional 3:7 to 7:3. Within 5000㎡, it configured 20 guest rooms, five galleries, and nine art installations; integrated formats including bookstores, agricultural product sales, and rural academies; combined living and exhibition functions, such as Gallery No. 5 merging ceramic art display with tearoom and restaurant functions.

Image 4: Functional transformation.

Functional transformation demonstrates extended use cycles and cascaded use. Spaces achieve value synergy through composite format design. Art exhibitions attract visitors while creating consumption scenarios for cultural tourism, with exhibits functioning simultaneously as artworks and functional items, such as ceramic tea sets and tableware available for purchase. This design creates diversified revenue sources from guest rooms, product sales, and dining while expanding employment types from room service to exhibition interpretation, dining service, and product sales.

3.2.3. Cultural Regeneration: From Heritage Preservation to Creative Activation

The project adopts cultural renewal design strategies, activating tangible and intangible culture. Five art galleries were transformed into thematic spaces: Courtyard No. 2's 'Face to Face' Modern Chinese Painting Gallery, Courtyard No. 5's 'One Land, One Water' Ceramic Sculpture Gallery doubling as tearoom and restaurant, Courtyard No. 6's Master Zhang Jie Gallery, Courtyard No. 7's 'Millennium Qiaotou' Plein Air Oil Painting Gallery, and the Field Observation Platform's 'Frozen Music' Architectural Art Gallery. Project documentation emphasizes: "the art gallery guesthouse courtyards also break the traditional pure exhibition model, ingeniously combining artworks with leisure and life."

Cultural renewal embodies value circulation mechanisms: ceramic tea sets serve simultaneously as exhibits (cultural value), functional utensils (use value), and merchandise (economic value). Their attached cultural experience enhances accommodation premium capacity. Free admission and regular training achieve "enriching minds while enriching wealth", enabling art to "take root and grow in villages", enhancing rural cultural capital (see Image 5).

Image 5: Cultural regeneration.

3.2.4. Community Co-creation

Community co-creation embodies participatory design practice. The project achieves co-creation through three levels (see Image 6): economically, establishing sales commission mechanisms; in cultural empowerment, art galleries open freely with training sessions, transforming culture from consumer goods to educational resources; in capacity building, implementing manager training programmes to enhance villagers' service skills and incubating local agricultural product brand 'Qingshi'.

Co-creation demonstrates dual circulation pathways. Capacity cultivation empowers villagers, promoting economic participation (employment income, art and agricultural product sales), retaining value within the community, forming sustainable investment. Cultural empowerment constitutes another circulation chain: viewing and training enhance identity and service quality, attracting visitors and increasing economic returns, which feedback to cultural development. Diversified revenue models reduce single dependencies, while culture-education integration enhances community cultural capital, reshaping rural value identity. This participatory model demonstrates how circular design transcends material circulation, extending to human, cultural, and social capital circulation.

Image 6: Community co-creation.

The four dimensions of circular design practice form nested and reinforcing systems: material circulation provides physical foundation, functional transformation creates spatial value, cultural renewal imparts symbolic value, and community co-creation realizes social value. Each level depends on the preceding level's support while providing enabling conditions for subsequent levels.

The core of this nested relationship lies in 'interface' design between dimensions. Material historical texture supports high-end cultural format positioning; multifunctional spaces provide carriers for cultural value economic conversion; open cultural-educational resources create capacity foundations for community participation; community service and product supply capabilities feedback to operational quality. The four dimensions are not simply additive but achieve value mutual conversion and amplification through carefully designed connection points.

This systemic circular design integration power is difficult to achieve through single technical or commercial dimensions, revealing that successful circular design requires simultaneous intervention in material, functional, social, and cultural systems, constituting an organic whole. Single-point breakthroughs often lead to 'restored but inactive' fossilization, 'changed but undifferentiated' homogenization, 'planted but unrooted' landscaping, or 'participated but not engaged' formalization. The key to transformation lies not in single-dimensional optimization but cross-dimensional integration — precisely the core value of designers as circular system integrators.

3.3. Economic Viability and Scalability: Systemic Circular Transformation and Transferability

3.3.1. Comprehensive Transformation Effectiveness

The project achieved significant transformation outcomes: abandoned dwellings transformed into comprehensive creative spaces at relatively low cost; currently housing art collections valued at approximately three million yuan, with annual exploitable value of approximately 10 million yuan; generating diversified revenues from accommodation, art and agricultural product sales, dining, and art exhibitions; creating employment positions encompassing service, interpretation, and sales.

More importantly, the project achieved multi-level self-circulating systems, demonstrating sustainability transcending short-term economic benefits:

Material Loop: Restoration → Use → Maintenance → Re-restoration
Traditional craftsmanship achieves living inheritance through routine maintenance.

Economic Loop: Revenue → Sharing → Reinvestment → More Revenue
Localized revenue distribution mechanisms promote sustained investment.

Cultural Loop: Art Integration → Educational Training → Innovation Creation → Cultural Accumulation
Transforming from cultural consumption venue to cultural production site

Social Loop: Capacity Building → Employment Income → Identity Enhancement → Sustained Participation
Cognitive transformation stimulates endogenous motivation

The four loops mutually support each other, constructing the project's self-circulation capacity. Unlike traditional projects dependent on continuous external inputs, Farewell to Cambridge achieved transformation from external driving to endogenous circulation through systemic circular design. It realizes systematic integration of material resources, functional potential, cultural assets, and social capital — precisely its core value as a transferable case.

3.3.2. Transferable Design Principles

Based on circular design practice, the research distils four transferable circular design principles:

1. **Adaptive Reuse Principle**: through design intervention achieving preservation, transforming traditional architecture, craftsmanship, and culture into contemporary functional spaces and cultural assets.
2. **Systemic Synergy Design Principle**: design should identify and activate multi-dimensional interconnections, with the key lying in discovering dimensional interfaces to create mutually supportive, mutually reinforcing value-added systems.
3. **Stakeholder Co-creation Principle**: design should construct mechanisms for multi-party participation and benefit sharing, creating participation, experience, and identity through design.
4. **Cultural Value Renewal Principle**: design should find connection points between cultural resources and market demands, enabling cultural preservation, innovation, and economic returns to form positive circulation.

The project demonstrates scalability potential, being promoted as a rural revitalization case, driving Qiaotou Town's transformation toward an art town. Scaling should follow a principles transferable, pathways innovative strategy: extracting the four core design principles above, conducting adaptive transformation according to different regions' resource endowments, market conditions, and cultural characteristics, rather than simply replicating architectural forms or format models. Design transferability lies in logic not form, in thinking not style.

Using the Farewell to Cambridge project in Wawu Village, Chongqing as a case study, this research explores how design innovation drives circular economic transition in rural areas. The study reveals that rural circular economic transformation possesses distinctive characteristics that differentiate it from urban and industrial contexts — it involves not only the circulation and reuse of material resources, but also the reconstruction of spatial functions, the renewal of cultural heritage, and the cultivation of community capacity.

The key findings are threefold. Designers function as 'circular system integrators', driving systemic transformation through four-dimensional synergistic mechanisms: material circulation achieves adaptive reuse of architectural heritage, avoiding resource waste from demolition and reconstruction; functional transformation converts abandoned dwellings into multifunctional creative complexes, creating value synergies that transcend traditional guesthouses; cultural renewal constructs innovative pathways from heritage preservation to cultural production; community co-creation operates through capacity building and benefit-sharing mechanisms. The four dimensions are mutually nested and reinforcing, forming a closed-loop system with self-circulation capacity. The research distils circular design principles applied in project practice: adaptive resource integration, multi-dimensional synergistic innovation, multi-party value coordination, and cultural-economic fusion.

Theoretical Contributions
First, the research extends the application boundaries of circular economy and circular design from industrial manufacturing and urban contexts to rural development transformation. Second, it transcends the tendency of circular economy research to emphasize material circulation, expanding from material circulation to multi-dimensional circulation encompassing function, culture, and society. Third, it redefines the role of designers — from traditional form-makers or technical problem-solvers to 'circular system integrators', demonstrating the unique value of design as a cross-disciplinary integration tool in complex system transformation. Finally, the research provides a practical framework of transferable principles, innovative pathways for rural sustainable development, transcending simple technical solutions or model replication.

Practical Implications

For policymakers, there should be a shift from purely financial investment to systematic capacity building and institutional support, establishing policy environments and evaluation systems that encourage circular design innovation. For design practitioners, cross-disciplinary integration capabilities must be cultivated, transitioning from an external expert intervention model to a participatory collaborator co-creation model, understanding and respecting the knowledge and needs of rural communities. For operators, the long-term value of circular models should be emphasized rather than short-term economic returns, seeking balance between commercial viability and sociocultural value. For academia and practitioner communities, there is an urgent need to accumulate more circular design knowledge, methods, and cases suitable for rural contexts, constructing dialogue platforms between theory and practice.

Research Limitations and Future Directions

As an exploratory study of a single case, the findings require validation of their universality and scaling conditions through additional cases. The research is based on data from the project's early operational phase; its long-term sustainability and the stability of circular mechanisms require continued tracking. Additionally, the research primarily employs qualitative methods, lacking quantitative assessment of circular benefits.

Future research can deepen in the following directions. First, conduct comparative case studies exploring differentiated circular design strategies under varying geographical environments, cultural backgrounds, and resource endowments. Second, undertake longitudinal tracking research to dynamically observe the evolution, challenges, and adaptation processes of circular mechanisms. Third, develop quantitative assessment methods, establishing benefit evaluation indicator systems for rural circular design to comprehensively measure the effectiveness of circular transformation across economic, environmental, social, and cultural dimensions. Fourth, explore the integration of digital technologies (such as IoT, blockchain, and artificial intelligence) with circular design, investigating how digital tools can enhance the efficiency, transparency, and resilience of rural circular systems.

The circular economy provides a new development paradigm for rural revitalization, with design innovation playing a pivotal integration role in this transformation. This research represents merely a starting point, with more scholars and practitioners working to jointly advance theoretical construction and practical innovation in rural circular design, contributing wisdom toward achieving a sustainable, resilient and valuable rural future.

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The Regenerative Fashion Hub: Design and Research Skills for Establishing a Culture of Sustainability in Society

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Abstract

In this paper, we present a review of practice – a reflection on being a translational design-researcher in circular economy research. Our approach to circular economy research is underpinned by a belief that for stakeholder communities to adopt sustainability practices, the means to enact them must be embedded in society. Constituents of stakeholder communities play different roles in the circulation of materials or resource flows – for which they require the means to enable such flows. For these stakeholders to have relationships and to transact they need to understand the value of the materials to their role. We present the role of the design-researcher in working in interdisciplinary and transdisciplinary teams situated in a stakeholder-engagement platform – the *Regenerative Fashion Hub* – to add value to resource flows in place-based circular supply chain systems as they transition from waste to apparel product. Through doing so, we provide insights on the skills designers need to design for a zero emissions world.

Keywords: Interdisciplinary collaboration, research into action, transdisciplinary collaboration, translational design.

Introduction

The *Regenerative Fashion Hub* (RFH) is a design-led stakeholder-engagement platform (see Figure 1) for visioning, enacting and innovating scalable and economically viable solutions amongst industry partnerships and local government to catalyze society's transformation to a circular economy (CE).

The RFH was developed as part of the UKRI interdisciplinary Textiles Circularity Centre (TCC), one of the circular economy centres funded by the UK Research & Innovation Interdisciplinary Circular Economy Research programme (NICER). The approach of the TCC has been to demonstrate a value pathway for a circular textiles model by adding environmental, technical, economic, and social value to biowaste as it flows from recycling of waste, production of textiles, to consumption and reuse of apparel. And in so doing, design the *means* for stakeholder communities to practice circular economy in place-based settings.

Figure 1: The design layout of the *Regenerative Fashion Hub* in Shoreditch, London. Credit: Annabel Maguire

Sustainability needs to be embedded in our culture. It is only through direct and holistic engagement with all constituent stakeholders that design and research can help to bring about a significant change in the culture of production and consumption. Supporting small businesses and start-ups, innovators and makers, and promoting co-creation as a way of acquiring clothing on the high street is a focus of TCC to realize the ambitions of 'high reuse & less consumption of apparel' (Millward-Hopkins, Purnell and Baurley 2023). We do this through the *Regenerative Fashion Hub,* where we put our research on the high street in a public exhibition format to engage stakeholders in innovation activities (see Image 1).

Image 1: The *Regenerative Fashion Hub* at Rich Mix in Shoreditch, London. Credit: Chris Lee

In the RFH, we brought to life the concept of a 'social production network' (SPN) – a place-based supply chain system of diverse actors whose collective behaviours emerge into a CE. The SPN consisted of various stations that enable circularity of apparel (see Figure 2) in which we positioned research from TCC (see Image 2) alongside activities of businesses already engaged in the CE, e.g. repairers, upcyclers, waste collectors (see Image 3). We produced a journey map for constituents to choose their journey through the SPN based on their objective, e.g. to repair, reconstruct or alter a shirt.

In this paper, we present a review of practice by design-researchers on the skills they have brought to bear or have developed in order to turn circular economy research into action.

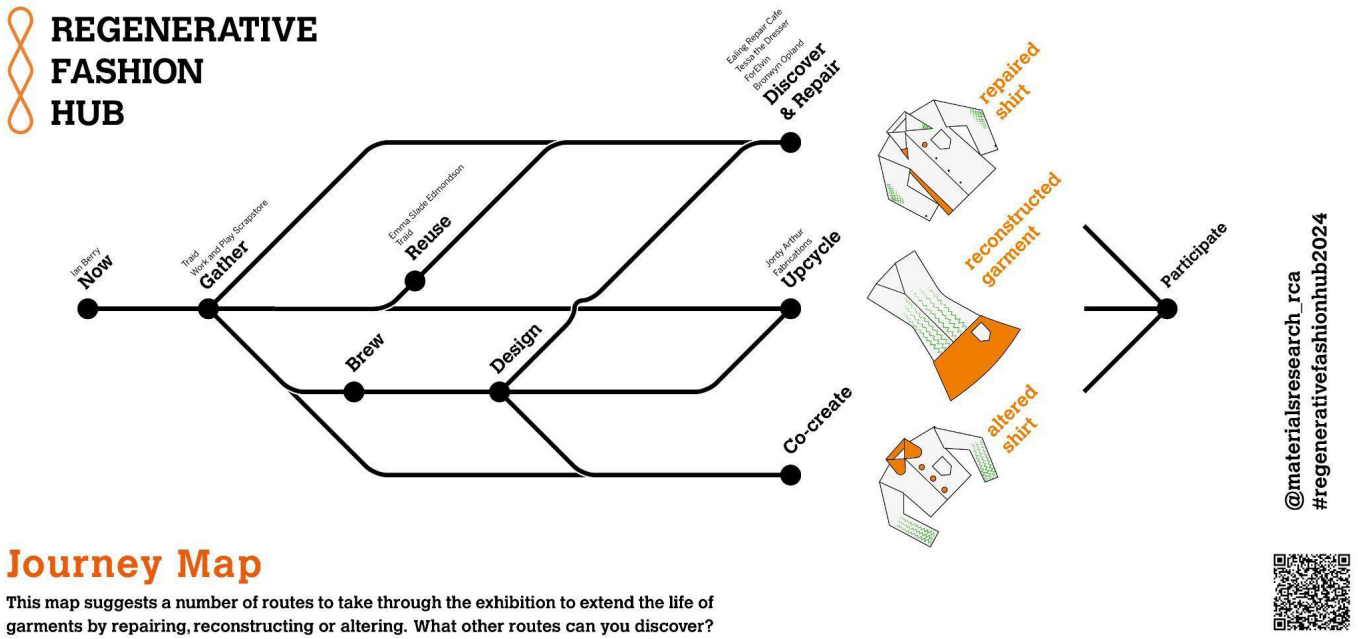

Figure 2: The *Social Production Network* journey map in the *Regenerative Fashion Hub.* Credit: Żaneta Muranko

Image 2: *Design* station featuring a showcase of circular waste-derived materials fabricated using 3D printing technology. Credit: Gianni Diliberto

Image 3: *Reuse* station featuring 'Nice Trash' by George Boros and Charlotte Budgen. Credit: Chris Lee

Skills to Turn CE Research into Action

The research programme of the TCC was comprised of three integrated strands of research (see Figure 3) which developed a range of circular design strategies: **Materials Circularity** to innovate circular bio-based textiles that have reduced environmental impacts and keep resources in use; **Consumer Experience** to position these materials in circular experiences that slow down consumption by satiating human wellbeing needs; and **Circular Supply Chain**, which put these strategies into a relationship in a localized way through collective behaviours by the design of a supply chain system.

The research of TCC was design-led – not just in terms of research but in terms of practice, which enabled the design team members to translate research into action. TCC oscillated between different modes of inquiry – at individual research strand level and at systems level.

At the individual strand level – through interdisciplinary collaboration and aided by the translational nature of their design backgrounds, the leads of research strands channeled and synthesized the work of the wider (interdisciplinary - spanning technical to social) consortium to develop circular strategies and tools.

At systems level – we were holistic and vision-directed to position and test these strategies and tools. We developed a stakeholder-platform – the *Regenerative Fashion Hub* - to create a vision for a 'social production network', and to facilitate experimentation in a setting that reflected the complexity of real-life systems. To enact this vision, we took a transdisciplinary approach to put our circular strategies and tools in a relationship with stakeholders who are already circulating apparel and materials in their local communities, and thus "transform the relations between science, technology and society" (Barry and Born 2014).

The role of the design-researcher has been to lead the development of these strategies by adding different dimensions of value to waste, and position these strategies in the CE framework of a 'Social Production Network' using Translational Design (Hornbuckle 2022) amongst interdisciplinary and transdisciplinary groups. This involved *prototyping* to translate complex research findings into tangible, understandable applications for real-world impact. Research leads were design-trained but had in-depth knowledge of areas of science and technology, which equipped them with the ability to translate between disciplines and to oscillate between working at the strand level and working at systems CE framework level.

The *Circular Supply Chain* research strand led the visioning and systems-level perspectives to conceptualize and build a social production network. Using a research mapping tool, the strand led workshops involving the *Materials Circularity* (MC) and *Consumer Experience* (CX) strands to sketch out a system design that was aligned with the required scenario, as identified by Millward-Hopkins, Purnell and Baurley (2023). They were asked to map the possible circular journeys a garment can undertake and specify the architecture and attributes of the 'social production network' required in enabling their flow.

Using an Actor Network Mapping (Latour 2007) exercise, MC and CX mapped out human and non-human actors against textile flow phases, as well as links and intermediaries, followed by flow configurations such as scenarios of reuse, repair, and refurbishment of apparel (see Figure 4).

This activity was aided by a template map they were asked to draw onto. This activity resulted in rough sketches of a 'social production network concept', which positioned MC and CX strategies in a CE framework together with other actors and strategies already in existence or that would be required (see Figure 5).

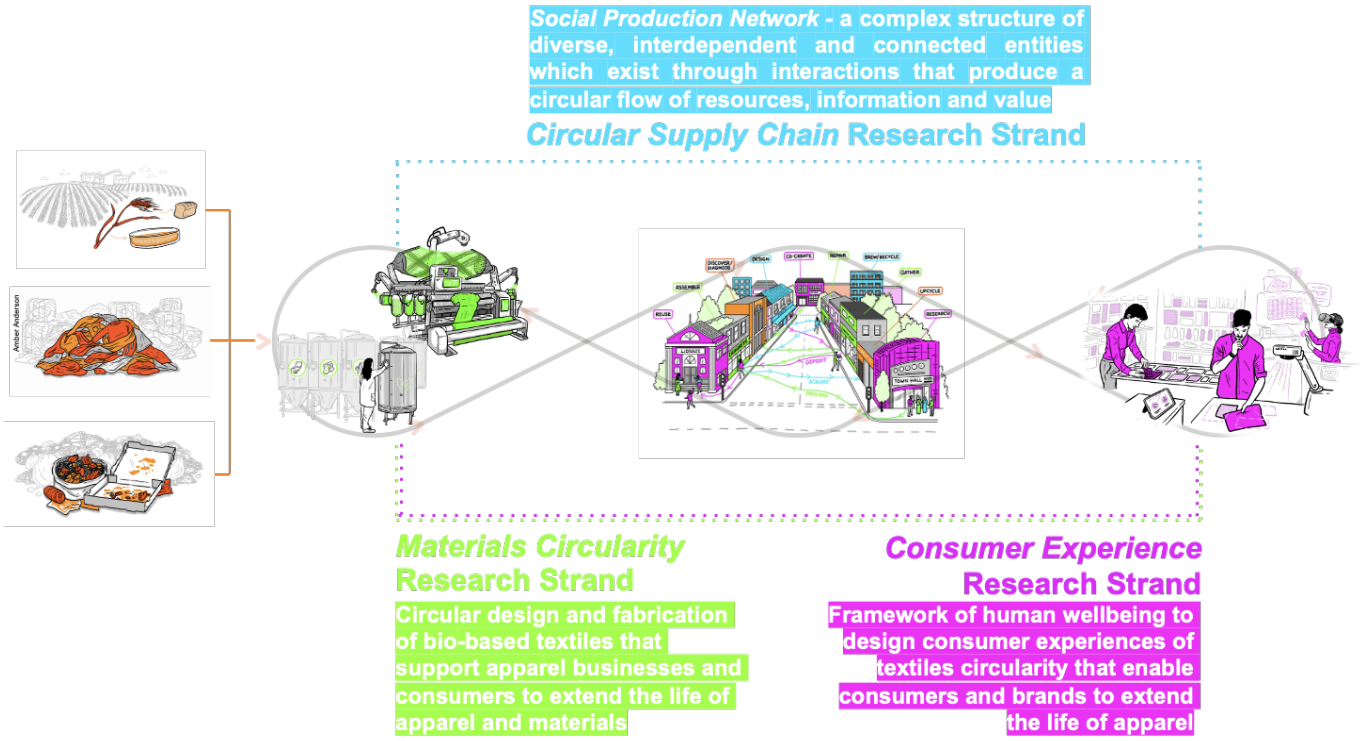

Figure 3: TCC was comprised of three integrated strands of research.

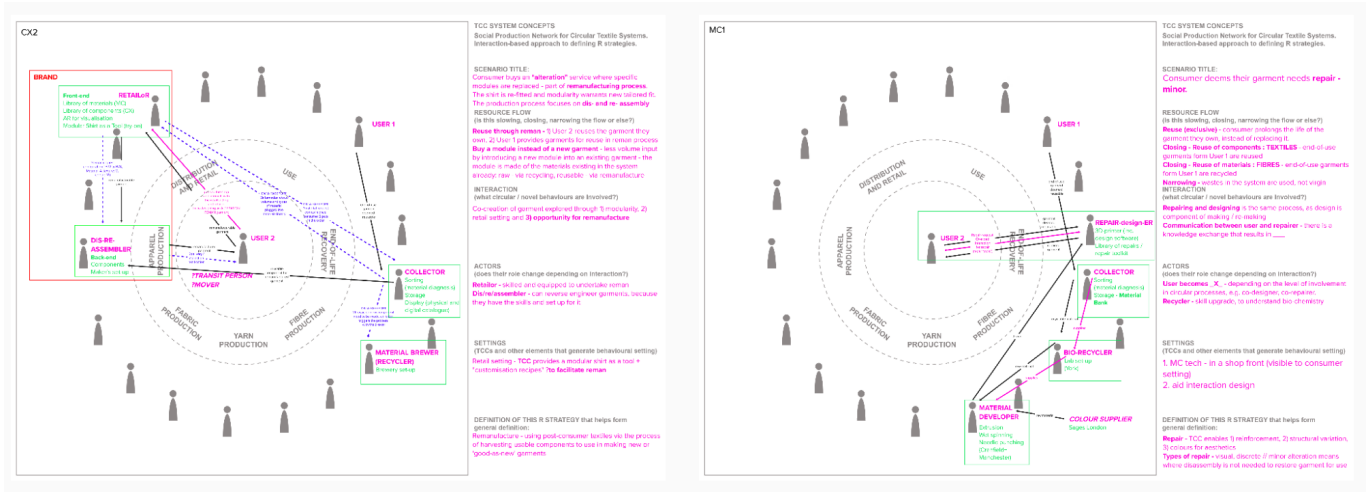

Figure 4: Map produced with the CX strand (left). Map produced with the MC strand (right).

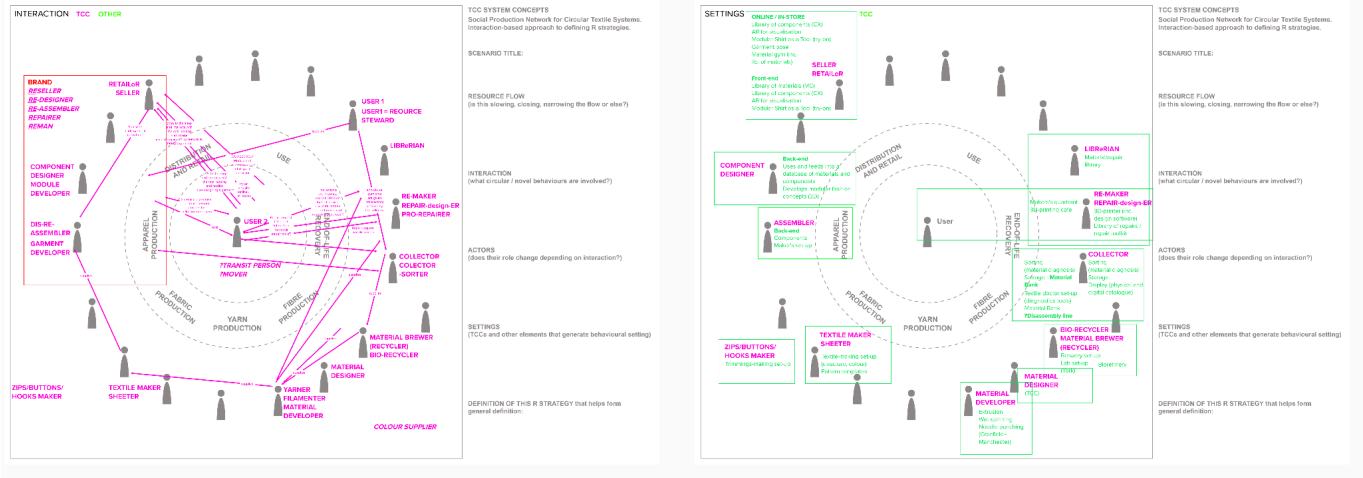

Figure 5: Rough sketches of a social production network featuring actors, interactions, settings.

Translational Design Reflections of Design Researchers

Materials Circularity

Materials circularity (MC) strategies included a visual card-based Materials Library[1] (see Image 4) to help designers understand and adopt TCC circular waste-derived materials and advanced manufacturing technologies; a Circular Materials Design Toolkit[2] (see Image 5) to help guide designers and brands to map alternative process flows towards circularity; and a Maintaining Materials Toolkit[3] (see Image 6) to redesign the application of advanced fabrication technologies towards maintaining materials in use.

Image 4: TCC Materials Library. Credit: Gianni Diliberto

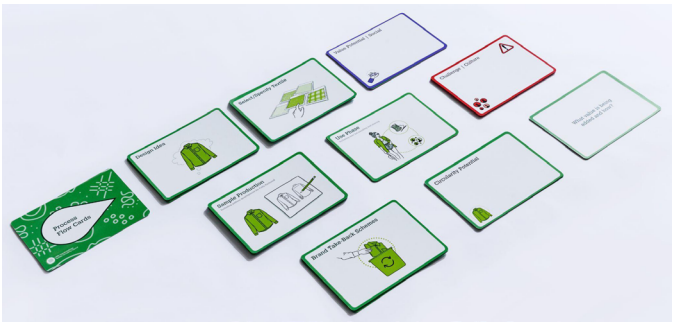

Image 5: Circular Materials Design Toolkit (process flow cards). Credit: Gianni Diliberto

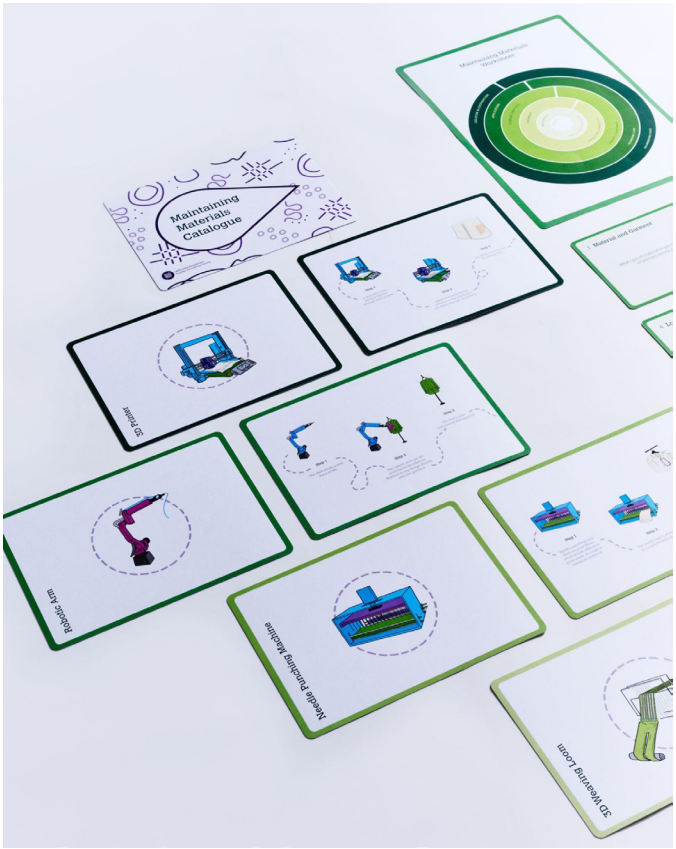

Image 6: Maintaining Materials Toolkit. Credit: Gianni Diliberto

1 https://textilescircularity.rca.ac.uk/resource/materials-library/
2 https://textilescircularity.rca.ac.uk/resource/circular-materials-design-toolkit/
3 https://textilescircularity.rca.ac.uk/resource/maintaining-materials-toolkit/

Translational practices in the MC strand involved the challenges of translating materials research to other disciplines within the consortium and the programme whilst working with scientific research partners in the following disciplines: biopolymer production, bioprocessing and biorefinery in biotechnology; fibre spinning, dyeing and chemical engineering in materials science; advanced manufacturing (additive manufacturing, nonwovens, and robotics) in engineering; and life cycle analysis and mass flow analysis in environmental sciences. Within the strand, we held meetings (in person and online) to share background research and ongoing activities, which helped facilitate collaboration.

Introducing the MC strand lead – Miriam Ribul: My skills are rooted in being a design-led, transdisciplinary researcher, adapting scientific methods into design practice, with a background in textiles and materials design for sustainability and circular economy. I completed my PhD integrating chemical engineering in materials science into design methods for circular textile fabrication and finishing processes and then led MSRC projects that applied my material driven textile design methodology (Ribul et al. 2021) to the context of biological sciences, biotechnology and advanced manufacturing. In the TCC, the methodology involved exploration of scientific and technical material processes and translation of these processes into textile practices through visualization (illustrations, tools, and proxy materials) and validation of experiments (feedback from scientific partners) in the Materials Library and Materials Showcase, followed by activation of new circular material design processes through prototyping and co-creation with scientific partners to demonstrate circular material visions in the Maintaining Materials Toolkit and 3D printed reinforced textiles.

The translational design challenge was to integrate circular design possibilities within the technical materials research of partners investigating transformation of wastes into bacterial cellulose and fabrication techniques for the production of new fibres and textiles, as well as life extension of textile materials. To achieve this, I oscillated between the role of designer and researcher, where the design role helped turn ideas and technical scientific processes into actionable information within tools for the wider TCC research ecosystem.

These skills supported the design-led interdisciplinary research:

- Translating materials to wider audiences and different stakeholders by specifying design tools that synthesize different lifecycle stages of circular resource flows, including the textile end of life/recycling, the fabrication, and the use stages, and how these tools can be applied in locations such as the RFH and in research studies with brands by using illustrations, samples, photography, and prototypes to bring ideas to life.
- Synthesizing scientific and technical challenges into opportunities for circular materials design based on envisioning, including futuring and systems thinking (use cases, application, production, end of life), as well as design skills (physical and functional attributes such as form, colour, and properties).
- Envisioning possibilities and where innovations can take place by being rooted in deep knowledge of circular materials design based on tacit knowledge resulting from circular economy practice research through design skills (fabrication, prototyping), as well as foregrounding the state-of-the-art of current circular economy practice research through research skills.
- Applying a systemic perspective of materials by situating these within their use contexts using envisioning and prospective thinking skills to consider scenarios of potential location, user interaction, or application.

Design-led strategies addressed a number of challenges to develop the following outputs:

1. **Mechanical, Chemical, Biological: from Conceptualization to Demonstration**
   A first technical review paper of state-of-the-art recycling technologies assimilated knowledge from across biotechnology into design-led research to position the conceptualized circular research innovation of closed-loop biochemical recycling of textiles (Ribul et al. 2021) and then demonstrate it in the TCC (Lanot et al. 2024). Synthesis skills identified the gap in closed-loop biochemical processes through the literature review and informed the bio-waste feedstocks in the circular resource flow. Interdisciplinary collaboration and leadership skills helped transform this gap into a programme of materials circularity research with partners to demonstrate the biochemical recycling processes of bio-wastes in lab-based experiments.

2. **The Materials Library: Visualizing and Materializing**
   The library was a necessary step in translating the processes within the strand's academic partners and with the consortium. Materials research takes time and the scale of material samples at which they can be produced is limited due to the lab-based processes. Creating this library required multiple interactions within the strand to devise its content and categories, which were defined based on a circular design approach combining technical descriptions of fabrication and properties with design skills of systems thinking for futuring and positioning within a circular economy (value potential, circularity potential, and customization of processes) that informed design possibilities for communication to a graphic designer to collect this information. Two processes helped to devise and demonstrate initial design possibilities with these materials: (1) *visualizing* skills involved producing photography that focused on zooming into the material to convey its construction due to limitation of samples as well as illustrations, which required partners to share information about their work, and consultation and feedback on the content of the cards; (2) *materializing* skills devised a materials showcase through lab-based samples to convey lab-based processes at a scale that is accessible to designers and wider audiences, and complementing this through prototypes as well as proxy materials using commercially available textiles, where lab-based samples were not available.

   Building on the Materials Library, we held a strand workshop to explore how circular design approaches of creative material differentiation and material longevity explored in the Circular Materials Design Toolkit (CMDT) studies with apparel industry and brands could be implemented in fabrication processes. Material longevity was explored in the context of repair and durability, and CMDT included discussion on printing material finishes. Design skills of planning material samples and ideating of samples included considerations of different processes that could be combined (see Figure 6).

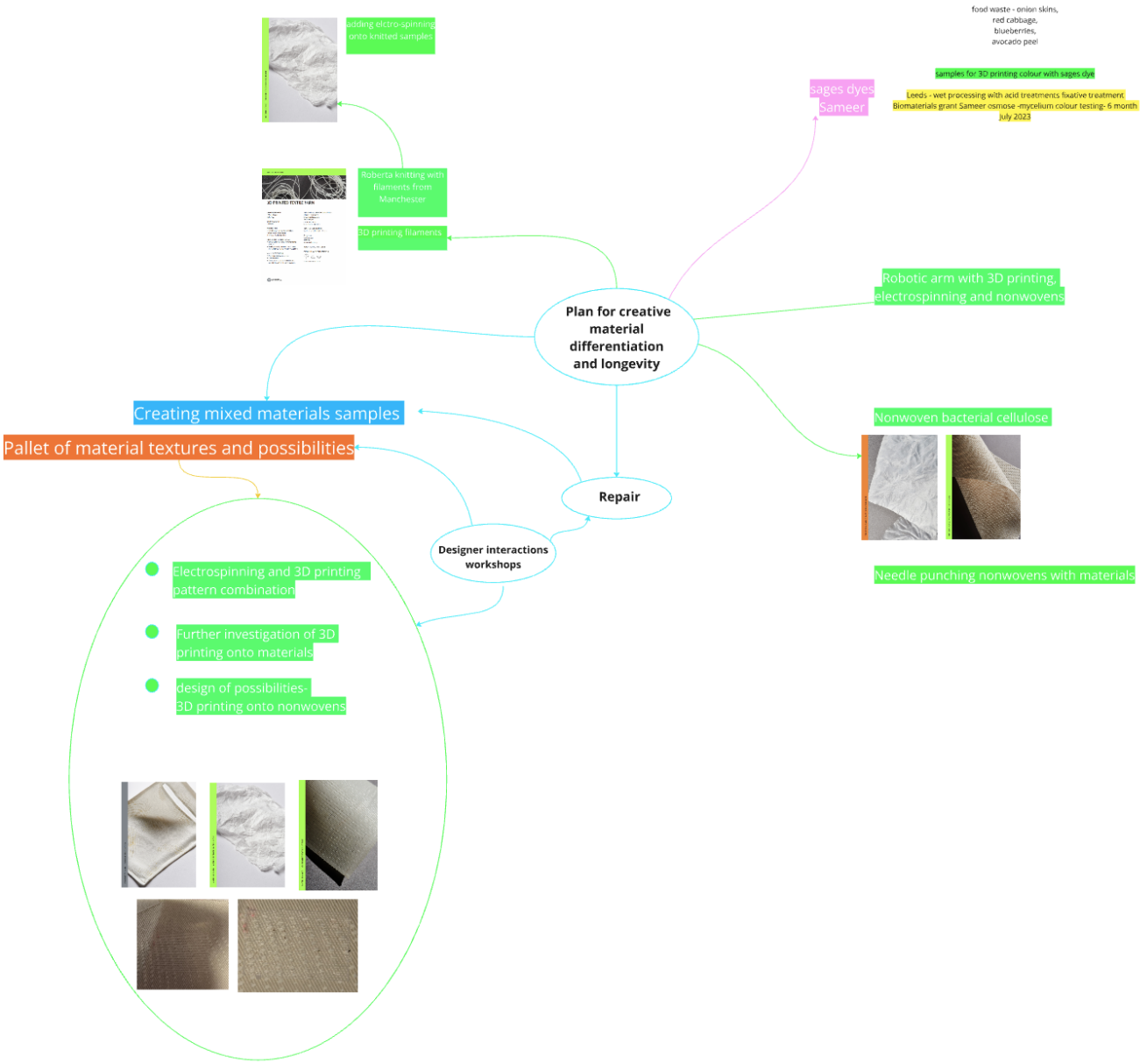

Figure 6: Material planning ideation and mapping of combined processes for repair within material longevity.

3. **The Circular Materials Design Toolkit: Activating Research into Practice**
The Toolkit was designed to activate the Materials Library in industry supply chains by getting designers to think about process flows. We needed to integrate new technologies into industry practices, however we saw that process flows are very individual, and that we needed user insights to understand user process flows and how they change using new technologies. We developed a process flow map to help designers reflect on their process flows by demonstrating key stages in a circular supply chain and their different variables from textile selection to product prototypes, use phase and end of life processes into one standard linear approach, and then split these stages into process flow cards. The location of the activation of the Materials Library within a brand's supply chain prompted participants to apply design skills of envisioning, futuring, and systems thinking. Facilitation and workshop planning skills helped to design and deliver a set of three studies with participants from 14 brands to map participant process flows. Workshops adopted a user-centred approach and asked participants to redraw process flows after introduction of a selected technology. We then incorporated recommendations into the next steps, and built a Maintaining Materials Toolkit that addressed the gap in tools that enable process flow changes in the use phase of circular materials.

4. **3D-printing for Reinforcement and Repair: Prototyping**
This work addressed two challenges: (1) the integration of circular design into fabrication processes required aligning partners across a shared goal of material longevity, which was achieved through monthly presentation of prototyping and designing of the Maintaining Materials Toolkit as well as 3D printed samples; (2) the scale of circular materials in scientific research and in industry. The design research conceptualization of 3D printed bacterial cellulose onto textiles for reinforcement and repair addressed both challenges. Then, prototyping a collection of samples for the RFH showcase in in-person and online collaboration through meetings and lab-based experiments, sharing of updates, and co-creating solutions iteratively while applying synthetic thinking and empathy with postdoctoral researchers focused the translational aspect on the technical challenge (devising a print paste and testing a printer for bacterial cellulose), and the design challenge (the patterns that can be printed within the technical limitations, and the applications these can enable). Presenting this approach in strand meetings informed other scientific partners in exploring material longevity.

5. **The Maintaining Materials (M²) Catalogue: Envisioning Application Scenarios**
   The challenge was to apply material longevity concepts to advanced manufacturing technologies in development. Building on the 3D printed samples, this process involved synthesizing skills to redesign current advanced fabrication processes for circular materials within current use phase interventions relying on craft practices to conceptualize use cases in the Maintaining Materials Catalogue. Decision-making for this redesign process involved empathy for the target audience of designers and makers by using visualization in illustration for the communication of potential process steps, and the design of a worksheet to retrace the decision-making process in the envisioning of these use cases in order to help participants design their own. The M2 Catalogue and worksheet build the Maintaining Materials Toolkit. Working with partners to understand and illustrate these technologies and their design possibilities informed use cases for studies with industry participants, resulting in 60+ concepts.

Research insights revealed the dimensions of value produced, including:

- Technical: where 3D printing of circular materials (Morrow et al. 2025) can support brands to innovate repairs whilst creatively differentiating themselves, and design skills in aesthetic properties through print design of patterns enhanced the functional skills through improved reinforcement of materials in characterization;
- Social: through enabling cooperation between brands in ecosystems of reuse and sharing of advanced technologies in hubs;
- Economic: for brands to transition to models that enable care and maintenance in the use phase and do not disrupt their current supply chain;
- Environmental: through local recycling interventions using waste-derived feedstocks (Latour 2007) that reduce land use to grow crops, and divert waste from landfill and incineration.

In terms of how our research influenced industry and stakeholder communities: 29 businesses from SME apparel brands, materials/tech start-ups, and independent makers participated in research and knowledge exchange activities, of whom five materials start-ups introduced circular processes, and three designers/brands were influenced to produce and/or adopt bio textiles.

Consumer Experience

Consumer Experience (CX) strategies included the Circular Experience Toolkit[4] (CET) (Jewitt et al. 2025) (see Image 7), a card-based practical resource that helps fashion professionals create consumer journey scenarios that stimulate meaningful experiences throughout a product's lifecycle. The CET operationalizes the *Wellbeing Framework for Circular Consumer Experiences* (Petreca et al. 2025), which reveals insights about behaviours that would slow down consumption. While the CET provides the 'how,' that is, enabling the design of products, services and experiences that make circular practices intuitive whilst contributing to wellbeing (see Image 8), the framework provides the 'why,' positioning consumer wellbeing as a strategic necessity for a successful circular value chain and linking circular actions to personal and societal wellbeing. These two resources contribute to establishing a recoupling between waste flows and human wellbeing, enabling consumers to be active agents of change in new circular cultures of consumption. This integrated approach, combining theory and a tool, is essential for moving the textile industry from intentions to effective, consumer-centric action.

Image 7: Circular Experience Toolkit. Credit: Gianni Diliberto

The Consumer Experience (CX) research strand aimed to design consumer experiences that enable consumers to engage with the circular life of apparel whilst satiating wellbeing needs. This was situated in the complex challenges of positioning the new biobased materials being produced by the MC strand and doing so whilst supporting a new consumption paradigm that challenges the linear mode of operating, that is, purchase-use-dispose. Tackling these challenges required a holistic understanding of human wellbeing that balances hedonic and eudamonic dimensions (Huta 2016). To achieve this, we assembled an interdisciplinary team of human-centred experts in social sciences, psychology, neuroscience, human-computer interaction, and design. Taking a phenomenological approach, that is, viewing individuals, society, and the environment as integrated, enabled CX to provide a more situated and relational perspective than other human-centred or positivist approaches (Petreca et al. 2025)

Image 8: The Circular Shirt Builder configurable shirt to test dimensions of human wellbeing. Credit: Ezzidin Alwan

Introducing the CX strand leads Bruna Petreca and Carey Jewitt: Bruna Petreca has a background in fashion and textiles, design, technology and phenomenology, with a research focus on textile experience in physical and digital environments. This foundation is complemented by laboratory experience in textile technology R&D and postdoctoral research in materials experience, enabling a holistic understanding of material creation, characterization, applications, and use. Her research seeks to understand the attributes of material interaction, with the dual aim of connecting people with their material experience and transforming design and usage practices. Carey Jewitt brings her interdisciplinary training from fine art and media,

4 https://textilescircularity.rca.ac.uk/resource/circular-experience-toolkit/

sociology, sensory studies and multimodal discourse to research how the use of digital technologies shapes people's interaction, communication and learning in a variety of contexts. Throughout her work, Carey is engaged in interdisciplinary methodological innovation and has made significant contributions to the development of multimodal theory and methods. Together, we approached this complex space by combining design, materials science, social sciences, phenomenological, and interaction perspectives. This interdisciplinary knowledge of human experience is the foundation for our role as translators within the strand, effectively bridging technical, scientific, and experiential domains.

Our leadership approach consisted of facilitating the team to oscillate between three distinct, yet interconnected, research 'modes': analyze, create and immerse. This leadership framework was essential for effectively integrating research and practice. Mirroring John Cage's studio rule #8 ("Do not try to create and analyze at the same time. They are different processes"), we recognized that creation and analysis require different processes and, critically, a different epistemic stance from researchers.

Analytical stages (Analyze) required the team to draw on their different resources for data collection and analysis. The objective was to generate new knowledge, synthesize findings, and build on this synthesis to specify the subsequent research phase, enabling 'quantic' research jumps. Creative stages (Create) required the team to build on specifications generated in analysis stages to produce tangible elements that supported the creation of the new realities central to the strand's aim. Specifically, these included: new cultures of consumption where consumers are engaged custodians of resources. Creative and analytical stages happened sequentially, and the conclusion of each phase of creation and analysis enabled the team to add complexity to the challenge we were immersed in (see Figure 7). Immersion phases (Immerse) enabled us to move between strand-specific and broader TCC consortium challenges, whilst keeping alignment with the NICER programme objectives. These phases include constant reflection on the transformation pathway and how value was added/created through the new knowledge and propositions CX put forward. The first immersion phase consisted of immersing ourselves in interdisciplinary understanding of consumer experience; the second immersion phase consisted of extending the complexity of this understanding to encompass industry knowledge; and the third immersion phase consisted of further expanding this complexity to include citizens-consumers.

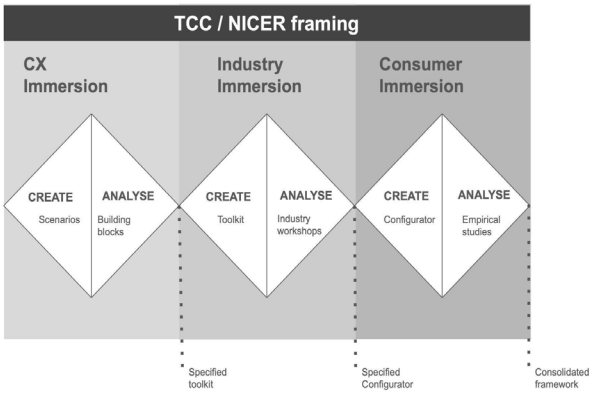

Figure 7: CX Research Process: oscillating between creation and analysis across three immersion phases.

The first immersion phase (interdisciplinary CX immersion) focused on interdisciplinary knowledge. We used systems thinking to map the complexity of consumer experience, circular economy, and wellbeing factors. This provided a foundation for the creation of scenarios to deal with the complexity of this design space (for instance, driving forces like fast-fashion vs. sustainability mandates and consumer eco-anxiety), using the skill of reframing to shift the focus from a complex system problem (How to make textiles circular?) to an actionable/solvable human-centred problem (What is the consumer interaction/engagement/experience that support circularity?). The analysis of the scenarios we created through empathic deconstruction allowed us to identify the core 'building blocks', i.e. design components, of consumer experiences favourable to circularizing textiles. These findings were synthesized and articulated as specifications for the scenario-building toolkit (Circular Experience Toolkit - CET).

The second immersion phase (industry immersion) required translating our theoretical findings into a practical tool. Utilizing the design skill of artefact prototyping to design the scenario-building toolkit (CET), which operationalized the 'building blocks' identified in phase one, to support the design of future circular consumer experiences. We then used the toolkit with a design-led approach in interdisciplinary collaboration to run scenario-building workshops with key industry stakeholders. The subsequent analysis of the scenarios built with industry enabled us to incorporate industry knowledge early on into our future model. Finally, using a skill of synthesis and abstraction, we formalized this knowledge into specifications for the Configurator – a conceptual space to house a range of future circular consumer experiences for systematic study and the basis of the third immersion phase.

The third immersion phase (citizen-consumers immersion) focused on experiential prototyping to test and validate our conceptual framework. We designed high-fidelity tangible tools and methods to bring the Configurator to life for citizen-consumers. The tools and methods included the Modular Shirt platform, Materials Gym method, and immersive experiences like AR Biofibre Explorer and Farfalla VR. The use of design artefacts enabled specialist, discrete empirical studies that provided deep-dives into specific wellbeing facets while maintaining coherence with the broader TCC narrative and alignment with the NICER objectives. Finally, the design skill of Synthesis and Iterative Refinement allowed us to consolidate the results from these multiple studies, rigorously refine the framework, and effectively specify its communication for broader impact. Specifying the communication relied on the designer's ability to create a compelling, accessible, and high-impact way to share the complex findings, which in this case meant turning a dense academic framework into a visual model.

Challenge	Challenge description	Strategy	Strategy description	Design skills
Interdisciplinarity	We convened a highly interdisciplinary team to ensure a holistic approach to human wellbeing; this also required balancing the different perspectives and ensuring mutual understanding.	Consistency and communication	Frequent ongoing meetings to discuss and elaborate on readings utilizing mapping, visualization and writing.	Systems thinking; visualization; synthesis
Complexity of WB	Literature revealed several wellbeing concepts which we had to individually define in the context of textiles' circularity, as well as understand their relationships.	Scenarios	To experiment with how these concepts relate to each other, we created six scenarios that would enable us to observe the different wellbeing concepts at play.	Systems thinking; futures thinking/reframing; world-building and visioning; storytelling and creating personas; empathy
Dynamics of WB	As we developed the scenarios and started to observe the wellbeing concepts in relationship, and realized that the wellbeing understood in this context was dynamically changing.	Identifying 'building blocks' of the scenarios	We analyzed the scenarios we created to understand the key ingredients/building blocks of scenarios, which included wellbeing. We ended up with the following categories that featured in our scenarios: personas, materials, wellbeing, technology, context, use/application, and sensory.	Deconstruction and Synthesis - through design thinking to understand human needs, identify critical forces at play, and translate those abstract elements into tangible components to design.
Futuring	As we designed our cards, we needed to be grounded in scientific plausibility, but include imagination of preferable futures.	Visioning and toolkit design	Created an illustrated toolkit to translate our conceptual universe. Particularly to design our technology cards, the design and technology researchers collaborated intensively to conceptualize and visualise futures that would push technology forward and innovate in the desired direction toward CE that engages consumers.	Research and ideation (grounded in current technologies but extrapolating into the future); artifact prototyping and visual communication
Real-world relevance	We needed to ensure that our developments were reflecting the barriers and opportunities in the industry.	Design workshops and toolkit validation	Designed and ran scenario-building workshops with industry stakeholders utilizing the CX toolkit. These supported the iterative development of the toolkit and its validation.	Stakeholder engagement; systems thinking; empathy; synthesis
Empirically test	To narrow down and refine the wellbeing concepts in the context of the TCC.	Design of configurator	A conceptual space furnished with tools and methods (Modular Shirt, Materials Gym, AR Biofibre Explorer, Guided Journeys, Farfalla VR) that enabled specialist deep-dives (discrete empirical studies) while holding the strand together.	Stakeholder engagement; world building and storytelling; systems thinking; artifacts prototyping (tangible representations of the future); empathy; synthesis
Consolidate WB framework	To communicate it effectively across disciplines and to the general public.	Illustration of the WB concepts and the framework	Design and social scientists work together to conceptualize the icons for the WB concepts. These were briefed to an illustrator who worked with the research team iteratively to achieve the outcomes.	Synthesis and iterative refinement; visual communication

Table 1: Challenges and corresponding strategies utilized by the CX lead and team.

Research insights revealed that a holistic approach to integrating and balancing the hedonic and eudaimonic dimensions of wellbeing provides an effective means of engaging consumers in textiles CE. For instance, playfulness and self-expression in garment life extension activities (see Image 8) make circular behaviours 'intuitive', leading consumers to view garments as adaptable investments rather than disposable items. The dimensions of value produced include: social, by promoting healthy consumption boundaries and giving people agency to participate in CE; environmental, by reducing consumption and waste; and technical and economic for brands to add value to their product offerings.

In terms of how our research influenced industry and stakeholder communities: Industry partners confirmed that the *Toolkit* addresses the challenge of envisioning and designing for circular textile futures. 191 citizen-consumers participated in research activities, with 26% of them reporting a change in consumption behaviour.

Insights from Systems-level Strategies

The *Circular Supply Chain* strategies included a Circular Systems Design Toolkit[5] (see Image 9), containing three tools, each of which has a complementary function for carrying out CE system design activities: A *Localized Circular System Design Tool* for co-designing a system in a city/town, and to understand its value for the local community; a *System of Systems Design Tool* for co-designing a wider interconnected system and to identify factors for scaling locally and across the UK; a *Systems Futuring Tool* for mapping the path to a desirable future, identifying the likelihood of a prospective system, and the necessary conditions for the system to be established.

Image 9: Circular Systems Design Toolkit. Credit: Gianni Diliberto

These tools were developed from the series of research methods the *Circular Supply Chain* research strand designed to gather data about localized circular supply chain systems. They found these methods useful to enable groups of diverse system actors (makers, brands, policymakers) to identify areas for innovation and to establish collaborations based on the circular systems they designed as communities.

Research insights revealed a framework of value of local CE supply chains in apparel-textiles to communities of constituents, and an articulation of value beyond solely financial considerations, instead centred on the often-ignored social component of circular systems, for example, enriched lives of people and regenerated community structures in a network of trust.

In terms of how our research influenced industry and stakeholder communities: 122 supply chain stakeholders (businesses, startups, designers, brands, makers, repairers, upcyclers, recyclers, NGOs, local authorities, policymakers and citizen-consumers) participated in research and knowledge exchange activities, of whom five partnerships were initiated, and four participants adopted circular supply chain configurations.

Insights from Transdisciplinary Strategy

We held two London high street activations of the *Regenerative Fashion Hub* (RFH), which were visited by 1233 people. Stakeholders found that the RFH platform provided an important opportunity for citizens, industry and policymakers to appreciate the holistic challenges in CE research and innovation and envisage a future in which they are active actors in CE systems. It helped stakeholder communities to place themselves in the wider social context and to provide a framing for what they already do in their communities; and it enabled them to see, to be informed, to visualize, to learn and to understand.

Our approach to designing CE frameworks has revealed a range of technical, economic, environmental, and social dimensions of value creation that would enable stakeholder communities to form CE ecosystems, which recognizes that the incentives to transition to circularity are not purely economic but are different for different stakeholders.

5 https://textilescircularity.rca.ac.uk/resource/circular-system-design-toolkit/

Conclusion

In this paper we have provided insights that speak to one of the aims of the World Design Congress London 2025 – to reveal the requisite skills for 'designing for a zero-emission world'. To conclude, we map our insights on skills to the key messages the congress sought to convey.

Research is critical to designing the future, design can help turn ideas into action, and design is critical in imagining and making a hopeful, regenerative future. At the systems level, we adopted a holistic and vision-directed approach to position and test our circular strategies and tools. We developed a stakeholder platform – the *Regenerative Fashion Hub* – to create a vision for a 'social production network', and to facilitate experimentation in a setting that reflected the complexity of real-life systems. To enact this vision, we took a transdisciplinary approach to put our circular strategies and tools in a relationship with stakeholders who are already circulating apparel and materials in their local communities.

At the individual strands level, this required the leads to facilitate the strands oscillating between strand-specific deep-dives to generate new knowledge and artifacts and maintain alignment with the TCC and NICER programme objectives. Leads also made sure to synthesize and communicate the value of strand contributions at the systems level for project-wide integration. Maintaining a cohesive approach was critical, which required the skills of envisioning and futuring, which involved keeping the strand working towards a shared vision and communicating how discrete contributions supported the tangible realization of our shared vision through the RFH, and ultimately met the TCC/NICER overarching objectives.

Design can play a technical and a creative, storytelling role. At the strand level and in collaboration between strands, MC and CX researchers developed technical and creative *prototypes* that both applied scientific and technological innovations (i.e. biochemical recycling, multisensory immersion) and design skills for form, function and use specifications. MC specified and designed tools in the Materials Library, Circular Materials Design Toolkit and Maintaining Materials Toolkit that tell the story of the different lifecycle stages of textile end of life/recycling, fabrication and use. By translating and synthesizing these lifecycle stages using illustrations of processes and design possibilities, material samples and their photography to convey their construction, and prototypes of 3D printed textiles, they bring advanced circular design concepts such as novel material longevity approaches to life. The Circular Experience Toolkit is a tool for scenario-building, which not only enabled the CX strand to manage interdisciplinarity and integrate industry input, but also offers the community a tool to create new, preferable future circular consumer experiences with textiles; storytelling is at the heart of the CET. CX and MC collaborated to create prototypes to enable multisensory immersion of citizen-consumers at specific points of the lifecycle of textiles. For example, the AR Biofibre Explorer was a cross-strand initiative to create an innovative tool designed to reconnect consumers with materials by demonstrating the wet spinning process for producing cellulose-based textiles. These tools and prototypes were then curated and featured in the RFH to address diverse industry and publics.

Unprecedented levels of collaboration are required. We have provided insights on the skills involved in interdisciplinary collaboration (from neuroscience and social sciences through to materials biology and engineering), as well as skills involved in transdisciplinary collaboration and working with layers of stakeholder communities, as we believe that everyone needs to have skills to participate in a circular economy.

At the individual strand level, through interdisciplinary collaboration and aided by the translational nature of their design backgrounds, the leads of research strands channeled and synthesized the work of the wider (interdisciplinary, spanning technical to social) consortium to develop circular strategies and tools. We managed each strand through immersion into partner activities, frequent meetings, in-person and online workshops, and presentations, which required empathy to facilitate collaboration and alignment.

Helping designers understand how to design for planet. The *Regenerative Fashion Hub* provides a model for how vision-driven design and research can enable context-specific and situated experimentation, reflecting the complexity of real-life systems. By connecting our research to existing stakeholders and creating high-fidelity prototypes of artefacts and tools required for our envisaged TCC future, we were able to build a (simulated) world and immerse people in this future reality. This allowed us to simultaneously iterate our designs and better understand and specify the requirements for achieving the TCC envisaged future.

Helping researchers see how they can bring more of the future to life. At the strand level, strands used different skills and strategies to align research visions across strands and in the consortium. Skills of envisioning and futuring were transformed into tools and methods, such as the Maintaining Materials Toolkit in MC and the Modular Shirt in CX research. Aligning a shared vision for material longevity with technical and scientific researchers in the MC strand was implemented through regular presentation of prototype development of 3D printed samples for reinforcement and of the M2 Toolkit. The Modular Shirt offered a platform for the CX strand to develop discrete empirical studies that examined different touch points between brands/designers/service providers with consumers over the product lifecycle; these studies ranged from design co-creation to neuroscience effort measures, and the insights emergent from them enabled CX to refine wellbeing concepts and consolidate the framework.

Connecting designers and researchers. In our research programme, we oscillated between two different modes of enquiry – at discrete research strand level and systems level. Our translational skills resulted from being both designer and researcher, as well as working in a transdisciplinary research space. This approach resulted in a series of outputs presented in the RFH, which connect both designers and researchers: demonstrating foundational advances in scientific and design research within tools and prototypes for designers to understand and apply textiles circularity concepts.

Acknowledgements

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Reimagining Design for Circularity: A Tool-supported Framework for Sustainable Industrial Design

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Abstract

Faced with mounting environmental challenges and the inertia of linear economic models, the *Design For Circularity* project led by Dassault Systèmes' DESIGNStudio – a think tank dedicated to innovation by design – aims to empower designers in the strategic transition towards circular economy. This research project explores the intersection of design, systems engineering, and life cycle analysis within the industrial ecosystem. The starting point of the project is a widely accepted estimate, that 80% of a product's environmental impact is determined during its design phase. However, a comprehensive scan reveals that the tools typically available to designers are fragmented, only partially relevant, or primarily engineering-focused. The goal of this research project is to bridge that gap by developing an integrated, tool-supported approach that helps designers evaluate and implement circular design principles from the earliest product development stages. *Design For Circularity* offers a robust, actionable framework for integrating environmental resilience into industrial design. By combining advanced modeling tools, qualitative evaluation, and a scalable methodology, the research project repositions designers as key players in building a more sustainable industrial future. It lays the groundwork for continued research and tool development in the field of circular design and sustainable innovation. And ultimately, help organizations transition to the circular economy.

Keywords: Augmented designer, circular design, framework for sustainability, industrial design, life-cycle assessment.

Introduction

The accelerating ecological crisis challenges the industrial world to reconsider the principles on which products and services are conceived, manufactured, and consumed. Over the past century, industrialization has largely relied on a linear economic model – extracting raw materials, transforming them into products, and discarding them at the end of life. While this model has fueled growth, it has also produced unsustainable levels of greenhouse gas emissions, waste, and resource depletion. Reports from the Intergovernmental Panel on Climate Change (IPCC) emphasize that without immediate action, global warming could exceed 3.2°C above pre-industrial levels by 2100, leading to irreversible environmental and social consequences (IPCC 2023).

In this context, design plays a pivotal role. The European Union has acknowledged that up to 80% of a product's environmental impact is determined at the design stage (European Commission 2020).

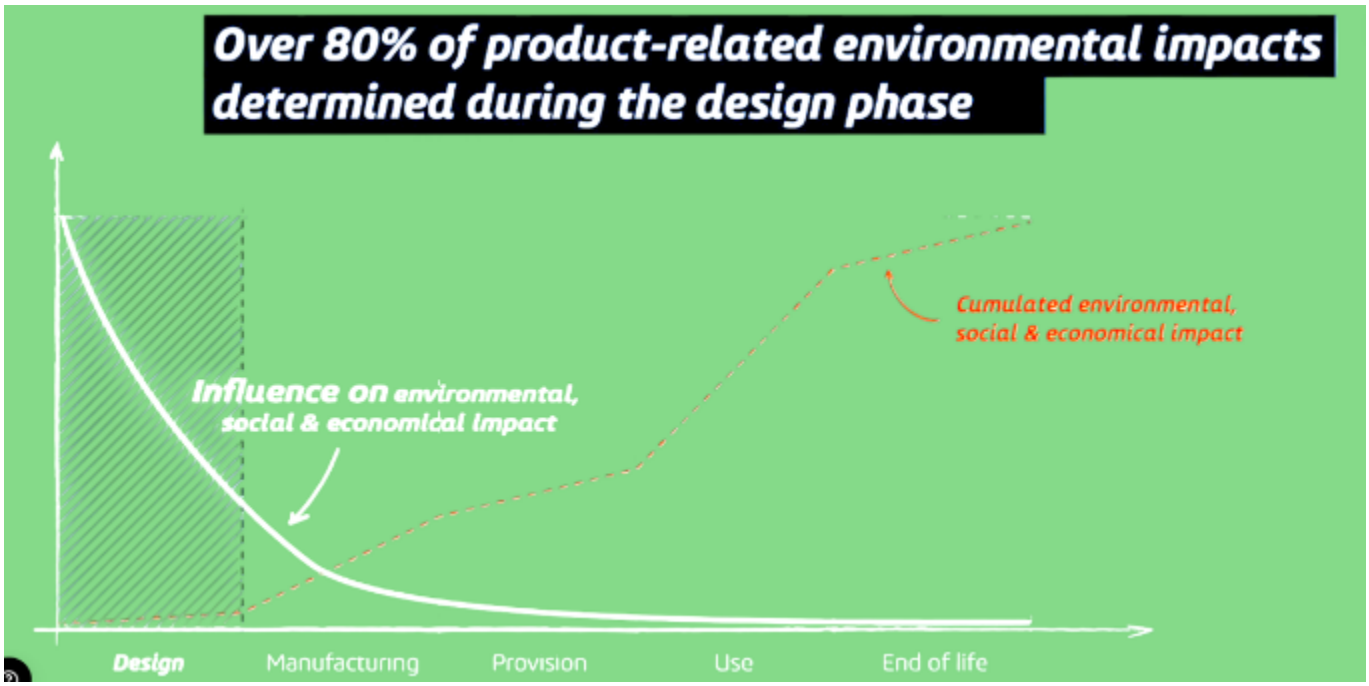

Figure 1: Environmental, social and economic impact at product design stage.

Designers shape not only the functionality and aesthetics of products but also their material flows, lifespans, and modes of use. Historically, design has often been complicit in sustaining a throwaway culture and consumerist dynamics. However, design also holds the potential to become a central driver in the transition towards a circular economy – a regenerative system where resources are maintained in circulation and waste is minimized.

This design research undertaken by the Design Studio of Dassault Systèmes, entitled *Design for Circularity*, aimed to develop an equipped methodology to help designers systematically integrate circularity into their practice. Through a combination of system modeling, life-cycle assessment and creative methods, the project proposes a new framework to bridge the gap between design, engineering and sustainability science.

The following work concentrates on this circular design approach, its theoretical foundations, methodological framework, tools, and case studies. It argues that by equipping designers with systemic methods and integrated digital platforms, industry can accelerate the transition towards sustainability and resilience.

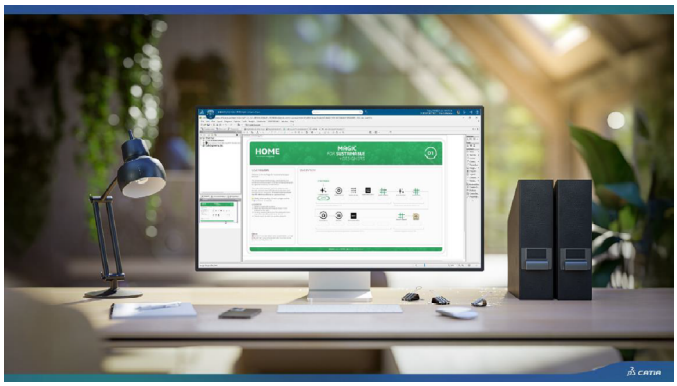

Image 1: Circular Design by CATIA.

The DESIGNStudio's Vision

Dassault Systèmes, historically rooted in aerospace engineering with the development of CAD software CATIA in the 1980s, has become a science-based company integrating design, engineering, and data across the entire product lifecycle. Within this ecosystem, the DESIGNStudio, led by Vice President of Design Innovation Anne Asensio, functions as a strategic laboratory where design is not only a creative discipline but also a catalyst for systemic innovation.

The studio's mission is to experiment with new design methods, test software solutions and processes with real industrial partners, and explore design's potential at the intersection of art, science, and technology. In the context of sustainability, the DESIGNStudio recognizes that design decisions directly impact industrial outcomes. Admittedly, designers might have historically been complicit in creating disposable products and promoting consumerism. Yet, this close association also provides a unique leverage: if design shaped the linear economy, it can reshape industry for circularity.

By equipping designers with systemic tools, the DESIGNStudio seeks to elevate design from aesthetics and ergonomics to strategic thinking, allowing designers to participate in business model transformation, regulatory adaptation, and ecological transition. Hence the *Design for Circularity* methodology.

Foundations of Circular Design

The circular economy emerges as a response to the failures of the linear model. Defined by the Ellen MacArthur Foundation, it is "a system where materials never become waste and nature is continually regenerated" (Ellen MacArthur Foundation 2019). Circularity involves strategies such as reuse, repair, remanufacture, and recycling, but it also requires systemic changes in value chains and business models. At the policy level, the European Green Deal (2019) and the Circular Economy Action Plan (2020) frame circularity as a cornerstone of Europe's climate neutrality strategy. New standards such as ISO 59004, 59010, and 59020 (2024) provide international guidelines for implementing, transitioning, and measuring circular practices. Together, these initiatives signal that circularity is no longer an optional trend but a structural necessity for industries.

Within design theory, Design Thinking emphasizes empathy, iteration, and creativity in solving complex problems. Its iterative cycles (empathize, define, ideate, prototype, test) are well-suited to exploring sustainable innovation. However, Design Thinking alone lacks the technical depth to address systemic environmental impacts. This is where Systemic Design comes into play, integrating systems engineering with design practices to consider entire value chains and ecosystems (Jones 2014).

The Danish Design Ladder, developed by the Danish Design Centre (2001), provides a maturity framework that illustrates how companies evolve from using design only for aesthetics (low levels) to employing design as a strategic driver of innovation and business transformation (high levels). The DESIGNStudio's work presented here extends this logic by proposing a Circular Design Ladder, adapted specifically to assess levels of circularity in design practice.

Thus, the foundations of circular design rest on three intertwined pillars:

1. Sustainability Science (life-cycle assessment, material flow analysis, climate policy).
2. Design Theory (design thinking, systemic design, strategic design).
3. Industrial Practice (digital platforms, product lifecycle management, collaborative tools).

By weaving these strands together, the *Design for Circularity* project situates itself at the crossroads of science, engineering, and creative practice.

Methodological Framework: Design for Circularity

The guiding research question of the project is: what circular design methodology, supported by Dassault Systèmes' tools, can be proposed to designers?

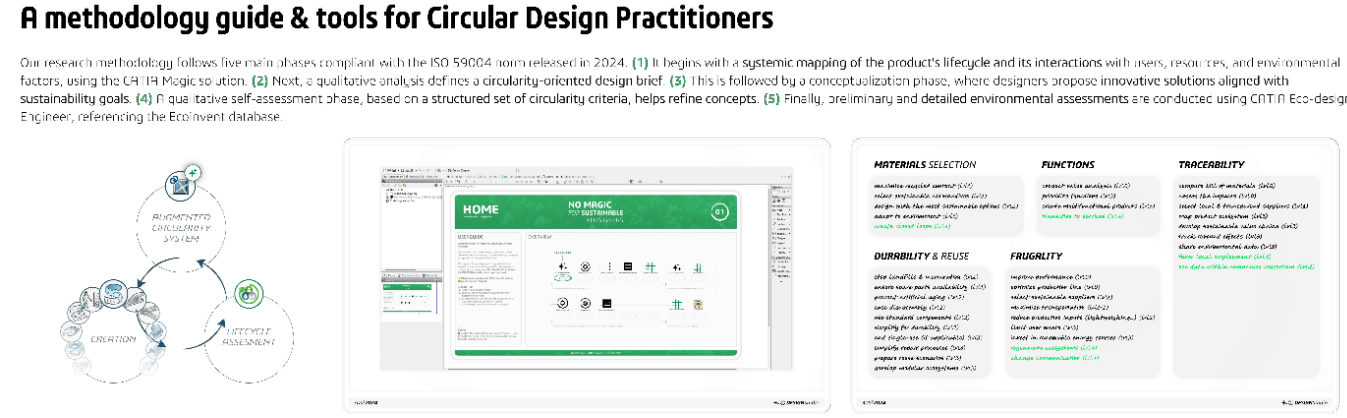

Figure 2: A Design Practitioners' guide.

The proposed framework is built on two complimentary axes:

1. Evaluation: Providing designers with a way to assess the circularity of their concepts through qualitative and quantitative criteria.
2. Integration: Embedding circularity directly into the design workflow, so that it becomes an intrinsic part of the creative process rather than an afterthought.

The methodology combines creative design practices with advanced digital tools, offering a systematic workflow:

- Systemic mapping of product lifecycles
- Qualitative assessment through circularity criteria
- Quantitative evaluation with Life-Cycle Assessment (LCA)
- Iterative redesign and conceptualization

This hybrid approach aims to empower 'augmented designers' capable of bridging creativity with engineering, and of influencing both product development and business strategies. An essential evolution in the necessary transition to a circular economy.

We believe that companies adopting this proposed comprehensive solution will benefit from a strategic roadmap, with the means to measure the impact of their transformation, enabling them to definitively move away from 'greenwashing' their company reputation.

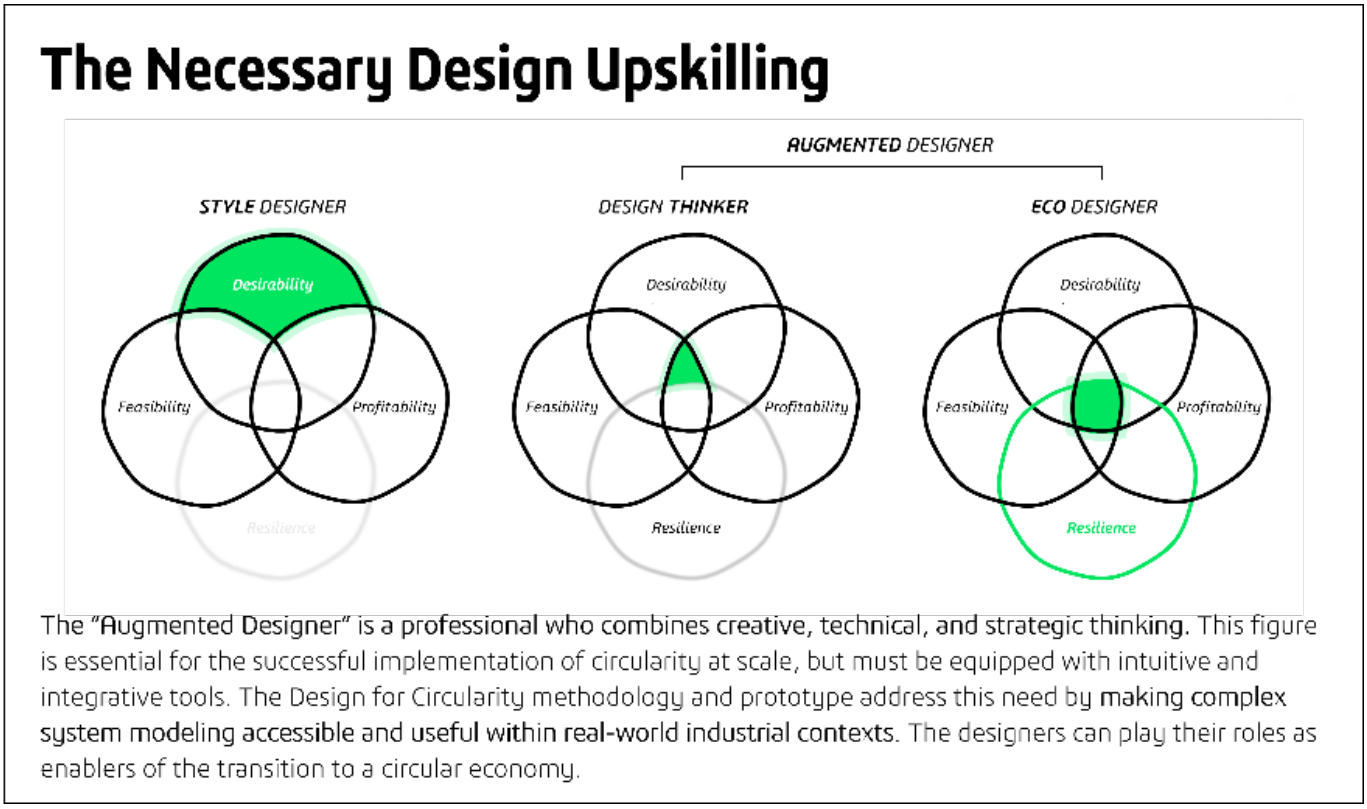

Figure 3: Upskilling designers with systemic tools.

The Circular Design Ladder

Another major outcome of the project is the Circular Design Ladder – a conceptual framework for evaluating the level of circularity in a product's design. Inspired by the well-established Danish Design Ladder, our practical tool defines five levels:

Level 0 (LVL0) → Standard product
- A standard product with no specific actions taken with the environment in mind.

Level 1 (LVL1) → Minor adjustments
- Minor adjustments in the selection of material, energy, or service suppliers, without challenging the development and production chain.

Level 2 (LVL2) → Product redesign – with two sub-levels:
- Downstream redesign targets incremental improvement of an existing product by evolving its structure, without altering the production chain.
- Upstream redesign aims to rethink the product from scratch through a disruptive approach, for example by integrating new, more sustainable manufacturing processes or materials – even if these introduce new technical requirements.

Level 3 (LVL3) → Reconsideration of the product within its ecosystem
- By observing the interactions between the product and its users, the designer can reimagine its functions and propose a new experience that is more environmentally respectful.

Level 4 (LVL4) → Major shift in mindset
- A fundamental change in mindset within the company, leading to cross-industry collaborations and a rethink of their economic models.

This framework simplifies a complex notion into a progressive evaluation scale, comparable to the Nutri-Score scale in food labeling. For example, a PET plastic bottle could range from LVL0 (standard, disposable) to LVL4 (multi-product fountain service eliminating single-use packaging).

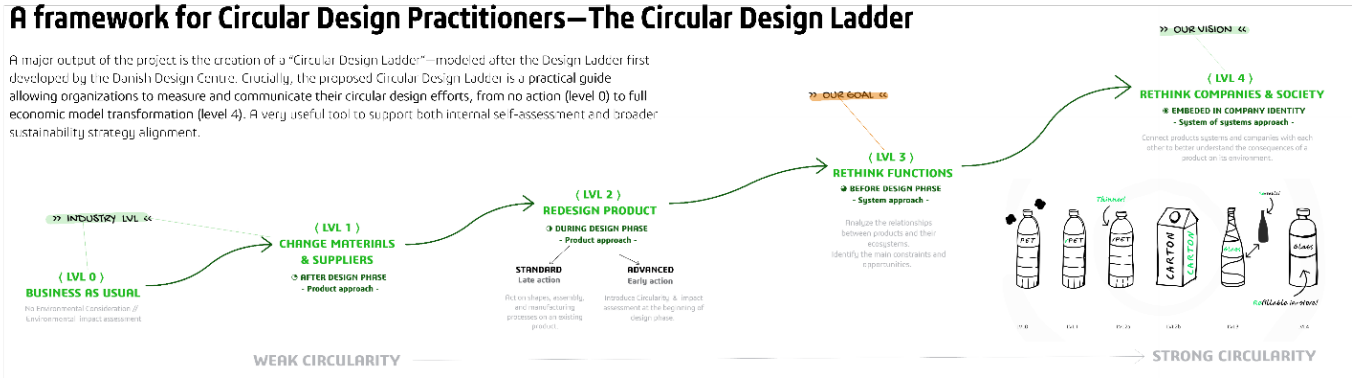

Figure 4: The Circular Design Ladder.

Unlike existing toolboxes such as IDEO's Circular Design Guide or Circulab's methodologies, which provide fragmented sets of tools, the Circular Design Ladder emphasizes a structured progression that companies can use for self-assessment, to benchmark, align and improve on sustainability. Crucially, the Circular Design Ladder also sets the stage for design to move the needle from minor material choices to systemic innovation.

Tools for Circular Design

Developed within Dassault Systèmes, the research project leverages the collaborative innovation potential of the company's 3DEXPERIENCE platform, a unified environment for industrials to reimagine products and experiences, and rethink business processes and operations.

Our research project was made possible thanks to software solutions recently made available such as CATIA Magic (for systems modeling) and CATIA Ecodesign Engineer (for Life Cycle Assessment), alongside project management capabilities and social engagement features, facilitating multidisciplinary collaboration, all on the same platform. With one objective: enabling the necessary paradigm shift from product-centred development, to user-centred, and ultimately planet-centred design.

CATIA Magic

CATIA Magic is a Model-Based Systems Engineering (MBSE) tool that supports complex systems modeling using languages such as SYSML. Originally developed for defense and aerospace, it allows the construction of logical diagrams, requirement trees, and systemic architectures. For *Design for Circularity*, CATIA Magic was adapted through simplified templates and guided navigation to make it accessible for designers, who are not traditionally trained in MBSE.

By enabling designers to map out the entire ecosystem of a product — materials, processes, stakeholders, users — CATIA Magic supports a systemic understanding that goes beyond aesthetics or ergonomics.

CATIA Ecodesign Engineer

Integrated into Dassault Systèmes' 3DEXPERIENCE platform, Ecodesign Engineer provides life-cycle assessment capabilities directly on 3D models. By connecting with the Ecoinvent database and implementing the Environmental Footprint 3.0 method, it allows designers to estimate environmental impacts (GHG emissions, water use, material footprint) based on product geometry and materials).
While traditional LCA tools like SimaPro are data-heavy and reserved for specialists, Ecodesign Engineer democratizes LCA by embedding it into designers' everyday workflows. This allows for early-stage eco-assessment, where design choices can be compared rapidly and efficiently before finalizing concepts.

Together, CATIA Magic and Ecodesign Engineer provide a dual lens: qualitative system mapping and quantitative environmental evaluation.

Case Studies and Applications

Throughout the research project, several case studies helped shape the methodology:

1. MIO (Urban Furniture): an eco-designed bus shelter integrating biodiversity. Although discontinued due to data access issues, it provided an initial testing ground for integrating ecological resilience into value analysis.
2. e-way (eVTOL Hub): a conceptual vertiport project explored LCA integration and systemic design, but its speculative nature limited its external credibility.
3. EECONE Remote Control: developed with the European ECOsystem for greeN Electronics, this case involved real industrial data, making it a credible testbed for systemic mapping and LCA integration.
4. EMF Co-Project: in collaboration with the Ellen MacArthur Foundation and multiple industrial partners, this project explored circularity indicators in real business contexts, though confidentiality limited data sharing.

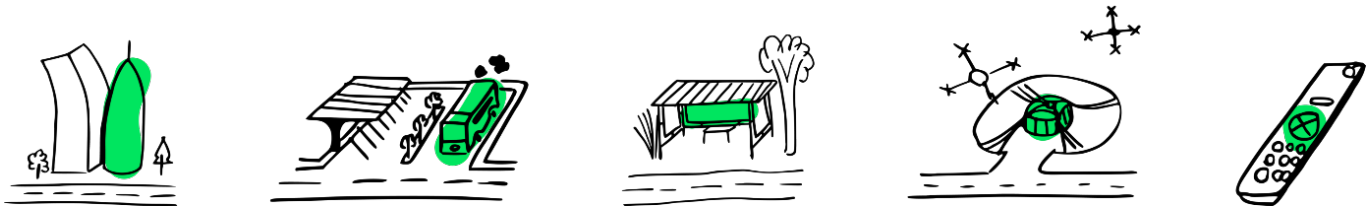

Image 2: Testing the Design for Circularity methodology at different scales.

These cases highlighted both opportunities and hurdles, such as the issues around data confidentiality and the difficulty of aligning speculative design with industrial needs.

Prototype and Systemic Methodology

The *Design for Circularity* project culminated in a prototype methodology implemented within CATIA Magic, structured around nine guided steps. Designers (alone or with specialized engineers) fill in information about product concepts, stakeholders, materials, and lifecycle processes. The system then supports:

- Mapping life-cycle interactions
- Assessing circularity through a decision matrix
- Iterating concepts to improve circularity scores

The team developed a set of circularity criteria covering five pillars defined by the French National Institute for Circular Economy:

1. Material selection
2. Durability and reuse
3. Frugality (resource reduction)
4. Functions
5. Traceability

This structured process transforms systemic design from a theoretical ambition into a practical workflow embedded in existing tools. The criteria serve as pragmatic design checkpoints and can be adapted to future standards (e.g., ISO 59004 or the EU Digital Product Passport). They aim to guide designers step by step in their decision-making processes, without requiring complete systemic transformation at the outset.

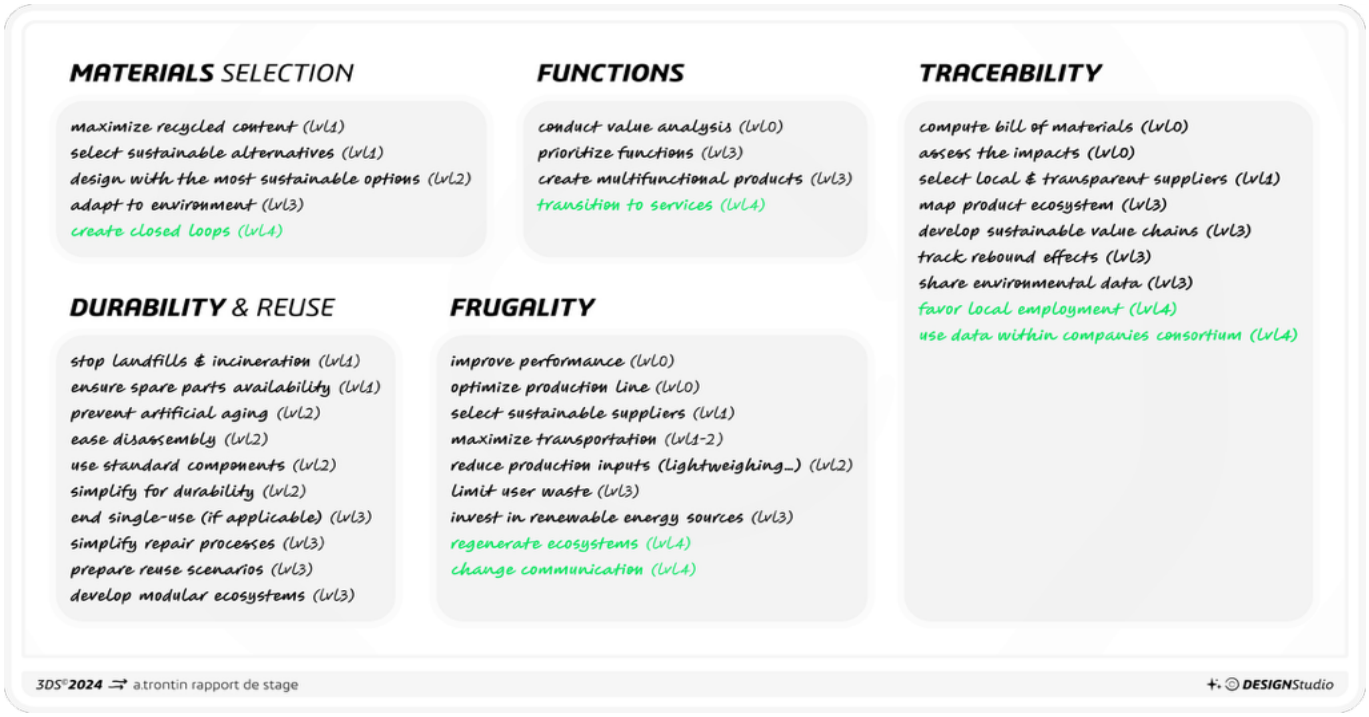

Figure 5: The five pillars of circular economy.

Critical Assessment

The *Design for Circularity* methodology demonstrates several strengths:

- Integration: it embeds sustainability into the design workflow rather than treating it as an external assessment.
- Collaboration: by bridging design and engineering, it fosters dialogue across silos.
- Anticipation: it prepares companies for emerging regulations, such as the Digital Product Passport (2024) in the EU.

However, challenges remain, including:

- Complexity: designers may find systemic tools overwhelming without adequate training.
- Data confidentiality: industrial partners often hesitate to share environmental data, limiting external validation.
- Adoption: without strong incentives, companies may resist shifting from linear models to circular practices.

Looking forward, the integration of artificial intelligence into design tools could further assist in exploring circular options, while industry-wide adoption of systemic design could scale impact.

Conclusion

The *Design for Circularity* project exemplifies how design can be reimagined as a strategic driver of ecological transition. By equipping designers with systemic methodologies, supported by digital platforms like CATIA Magic and Ecodesign Engineer, it bridges creativity with sustainability science and engineering rigor.

In an era where industrial practices must align with planetary boundaries, design cannot remain confined to style and usability. Instead, it must act as a lever for redefining business models, shaping regulations, and guiding consumption patterns.

As industries embrace circular economy principles, methodologies like *Design for Circularity* provide the necessary structure to transform ambition into practice. The challenge now lies in scaling these approaches, training future designers, and ensuring that design fulfills its responsibility as a cornerstone of a sustainable future.

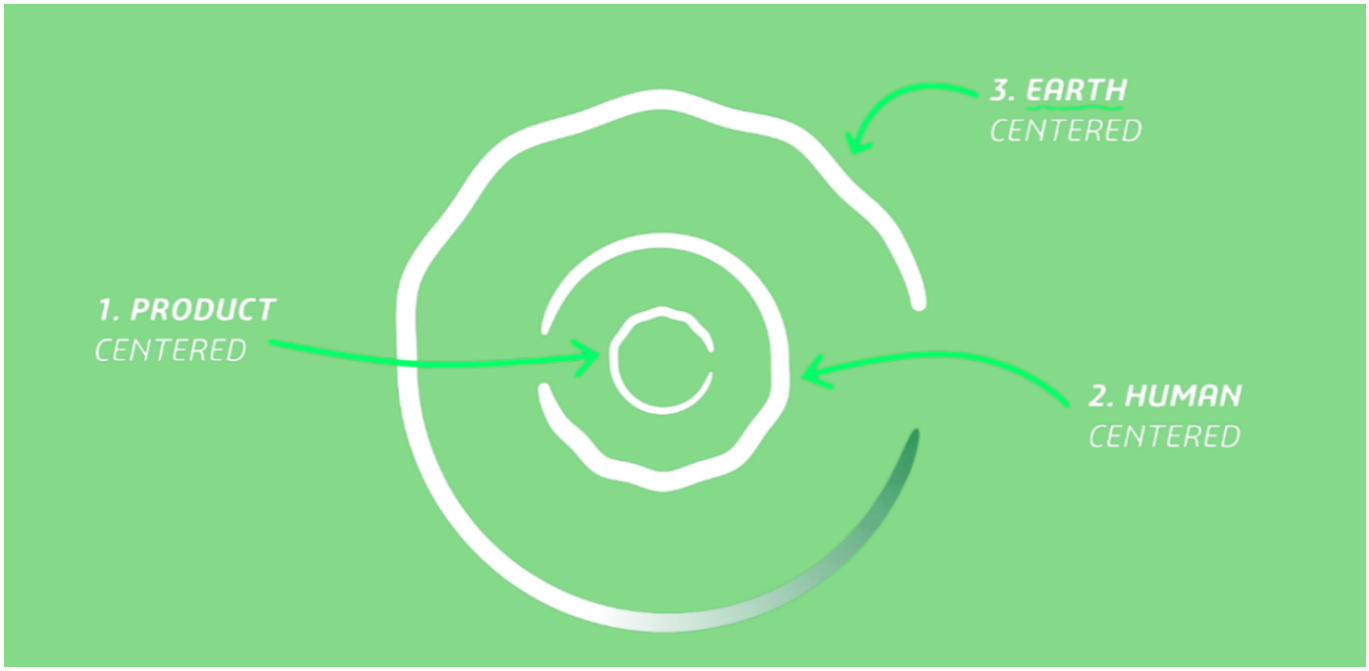

Figure 6: The path from product-centred to earth-centred.

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Reimagining Plastics: Civic Design Sprints, Material Futures, and the Circular Economy at V&A Dundee

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Abstract

Plastics have long shaped the material and social fabric of everyday life. From food packaging to electronics, fashion, and architecture, the material's ubiquity, durability, and malleability rendered it indispensable to modern consumption and design. Yet this material success came at a high environmental and social cost. As global plastic production exceeded 400 million tonnes annually, the issues of unsustainable extraction, waste mismanagement, and pollution, particularly in marine ecosystems, reached critical proportions. Plastics, once imagined as symbols of modernity and innovation, became entangled with global crises of environmental justice, climate change, and ecological collapse. This paper reports on a civic design sprint embedded within the *Plastic: Remaking Our World* exhibition at V&A Dundee in Scotland in 2024. The sprint aimed to explore design-led futures thinking for addressing plastic use and waste by programming public-facing engagement. The paper begins by examining the plastic pollution crises at both local and systemic levels, paying particular attention to circular economy principles, speculative design and material futures. It then goes on to describe the structure and process of the design sprint, positioning it as a framework for knowledge exchange and the cross-pollination of innovative ideas to environmental challenges. Insights from the sprint were gathered from participants through surveys, observation, and informal feedback, offering a multi-layered view of outputs and outcomes. The paper concludes by reflecting on the success of the design sprint as a driver to advance design-led approaches to public policy.

Keywords: Circular economy, civic innovation, design museum, design sprints material futures, plastics, speculative design.

1. The Plastic Pollution Crises

This project was situated within ongoing debates in design research on how material practices might transition towards more sustainable futures. Plastics, often vilified in public discourse, resist simple binaries of good/bad or sustainable/unsustainable. The challenge lies less in the material itself than in how it is designed, used, and discarded (Bennett 2010; Bakker et al. 2014). Design, as both discipline and praxis, offers critical tools for interrogating and reshaping these systems. Circular strategies such as reuse, repair, biodegradability, and closed-loop systems must be coupled with cultural and civic approaches that foster behavioural and systemic change (World Economic Forum, Ellen MacArthur Foundation, and McKinsey & Company 2016).

Plastics have long shaped modern life from packaging to electronics, clothing, and architecture precisely because of their ubiquity, durability, and adaptability (Meikle 1995; Freinkel 2011). Yet this success has come at significant social and ecological cost. Global plastic production now exceeds 400 million tonnes annually, driving unsustainable extraction, waste mismanagement, and marine pollution at critical scales (Geyer, Jambeck and Law 2017). Once symbols of modernity (Kula and Ternaux 2013), plastics are now entangled with climate change, environmental justice, and ecological collapse. Giving the pressing need to transition plastics toward a circular lifecycle, a report by OECD (2022) identified four "critical levers" to reduce the environmental impact of plastics: (1) developing recycled plastics markets by combining "push" and "pull" policies; (2) accelerating innovation for a circular plastics lifecycle; (3) enhancing national policy ambition with clear roadmaps to reduce microplastic leakage; and (4) strengthening international co-operation to create circular value chains and harmonized design standards. These recommendations highlight that systemic change requires innovation not only in technology but also in culture, governance, and practice.

UK Government policy frames plastic as indispensable yet profoundly problematic, bound up with overconsumption and weak end of life systems. Recent government research recognizes that without major intervention by 2035, most plastic will still rely heavily on virgin feedstocks, with only modest gains in recycling (DESNZ and DEFRA 2024). At the same time, they highlight the potential of consumer demand to accelerate shifts in the market. Indeed, surveys show strong public interest in durable, repairable, and reusable products, and packaging, one of the worst offenders in terms of waste, offers clear opportunities for reimagining how the public interacts with plastic in everyday life. However, even under ambitious scenarios where strategic intervention could support recycled content rising to 40-60%, the scale of waste and emissions underscores how far current systems are from delivering a circular plastics economy at scale.

From a Scottish perspective, the urgency is equally stark. Zero Waste Scotland (2022) reports that 1000 tonnes of plastic enter Scottish seas each year, nearly 700 million bottles are consumed annually, and only 37% of plastics are recycled. Nine out of ten items found on Scottish beaches contain plastic. These figures reveal both the scale of the challenge and the opportunity for civic engagement through design-led interventions.

Against this backdrop, this study sought to reimagine the role of cultural institutions specifically design museums in addressing environmental issues at both local and systemic levels. *Plastic: Remaking Our World* exhibition, shown at V&A Dundee between 2022 and 2023 (see Image 1) traced the 150-year history of plastics from their utopian beginnings to their contemporary environmental consequences, whilst showcasing examples of design experiments and innovations that point towards more circular futures (V&A Dundee 2022).

Image 1: *Plastic: Remaking our World* Exhibition at V&A Dundee 2022-2023. Credit: Michael McGurk

Embedded within the exhibition, V&A Dundee's Plastics Lab design sprint became a platform for participatory and speculative design, hosting a three-day sprint that engaged 30 students, supported by mentors from the design sector. Drawing on Design Sprint as a method (Knapp, Zeratsky and Kowitz 2016) and informed by participatory (Sanders and Stappers 2008), speculative (Dunne and Raby 2013), and transition design (Irwin 2015) approaches, the sprint produced early-stage prototypes that addressed civic challenges, such as, marine litter, single-use packaging, and biodegradable alternatives.

Situated within Scotland's evolving policy landscape, including the Circular Economy Bill and Zero Waste Plan, the study demonstrated how design can render systemic ambitions tangible, relatable, and actionable. As Manzini (2015) argues, social innovation through design begins by amplifying local initiatives and creating enabling platforms for experimentation. The Plastics Lab design sprint served as one such platform, linking global debates on material sustainability with community-engaged, culturally rooted design practice.

2. Circular Economy, Speculative Design, and Material Futures

Circular economy frameworks emphasize the need to move beyond linear models of production and consumption toward systems of reuse, repair, and regeneration (World Economic Forum, Ellen MacArthur Foundation, and McKinsey & Company 2016). The Ellen Macarthur Foundation usefully point out the meaning behind a circular economy while outlining its core principles, saying:

"The circular economy is a system where materials never become waste and nature is regenerated. In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting. The circular economy tackles climate change and other global challenges, like biodiversity loss, waste, and pollution, by decoupling economic activity from the consumption of finite resources."

While much of this discourse around the circular economy has been dominated by interconnected perspectives of business, policy and economics (Murray, Skene and Haynes 2017), speculative design offers a complimentary approach for tackling the crisis by critically imagining alternative material futures. Rather than providing definitive solutions, speculative design foregrounds ambiguity, prompting debate about what kinds of futures might be possible, desirable, or dangerous (Dunne and Raby 2013).

Applied to plastics, speculative methods open space to interrogate not only technical performance but also the ethical, ecological, and cultural dimensions of material use. Prototypes and scenarios become provocative boundary objects that invite participation and reflection thereby fostering what scholars term "material literacy" (Karana et al. 2015). Integrating circular economy principles with speculative

design could help to reframe plastics from a "waste problem" to a site of experimentation where new forms of value, responsibility, and sustainability can be collectively imagined and contested.

Transition Design, as proposed by Irwin et al. (2015), advocates for designing interventions that enable long-term, systemic societal shifts toward sustainability. In the context of speculative design and the circular economy, Transition Design offers a framework for envisioning and prototyping futures where social practices, production systems, and values align with regenerative principles. Scholars such as Tonkinwise (2019) and Manzini (2015) highlight how speculative design can serve as a catalyst for imagining such transitions — using design fiction to question linear consumption and provoke behavioural change. Together, these approaches position design not merely as problem-solving, but as a means of world-building that supports circular, equitable, and sustainable futures. This project treated the Plastic Lab design sprint as a means of cultivating such material literacy and as a means of 'world building'. However, it was also about behaviour change through design-led futures thinking. By engaging students and visitors in speculative prototyping, it encouraged participants to connect creativity with civic responsibility while exploring how design might anticipate and shape more sustainable futures.

3. The Civic Role of V&A Dundee

A central premise for embedding the Plastic Lab design sprint within the *Plastic: Remaking Our World* exhibition was to position the museum, not merely as a site of cultural display, but as an active space for experimentation and civic engagement (see Image 2). As such, the sprint both provided an educational experience for participants and publicly demonstrated design in action. This approach built on the growing body of scholarship that conceptualizes museums as laboratories for social innovation, capable of convening diverse publics and fostering dialogue around pressing societal challenges (Bason 2014; Julier 2017). Live prototyping and public presentations allowed visitors to witness and contribute to the design process, encouraging dialogue about material futures and the global implications of plastic waste. Furthermore, the project supported V&A Dundee's mission to deepen civic impact, promote inclusive innovation, and strengthen links with student communities.

Image 2: V&A Dundee's Plastics Lab design sprint during the *Plastic: Remaking Our World* exhibition (2022–2023), showing participatory workshop space embedded within the gallery.

4. Design-led Futures Thinking and the Plastics Lab Design Sprint

Amidst the escalating plastic crisis, Design-led Futures Thinking has emerged as a crucial framework for knowledge exchange and the cross-pollination of innovative ideas to environmental challenges. At its core, it is a human-centred approach that emphasizes collaboration, rapid prototyping, and iterative learning. Lockwood (2009) highlights design thinking's capacity to align people and processes with strategic goals, integrating diverse perspectives to influence both innovation and organizational practice. Through this framework the project aimed to address plastic use and waste through a public-facing model of hosting a design sprint in a public realm grounded in circular economy principles and speculative design.

Developed at Google Ventures, design sprints are iterative, time-constrained, and human-centred approaches for tackling complex challenges (Knapp, Zeratsky, and Kowitz 2016). The main drive for participation comes from the opportunity to interact and co-create with others (Hatt, Davidson and Carrion-Weiss 2023), as well as the chance to experiment with sustainability-orientated innovations (Buhl et al. 2019). To structure the design sprint, the UK Design Council's Double Diamond process model was used. However, it was adapted by compressing the conventional five-day format into three days (see Figure 1).

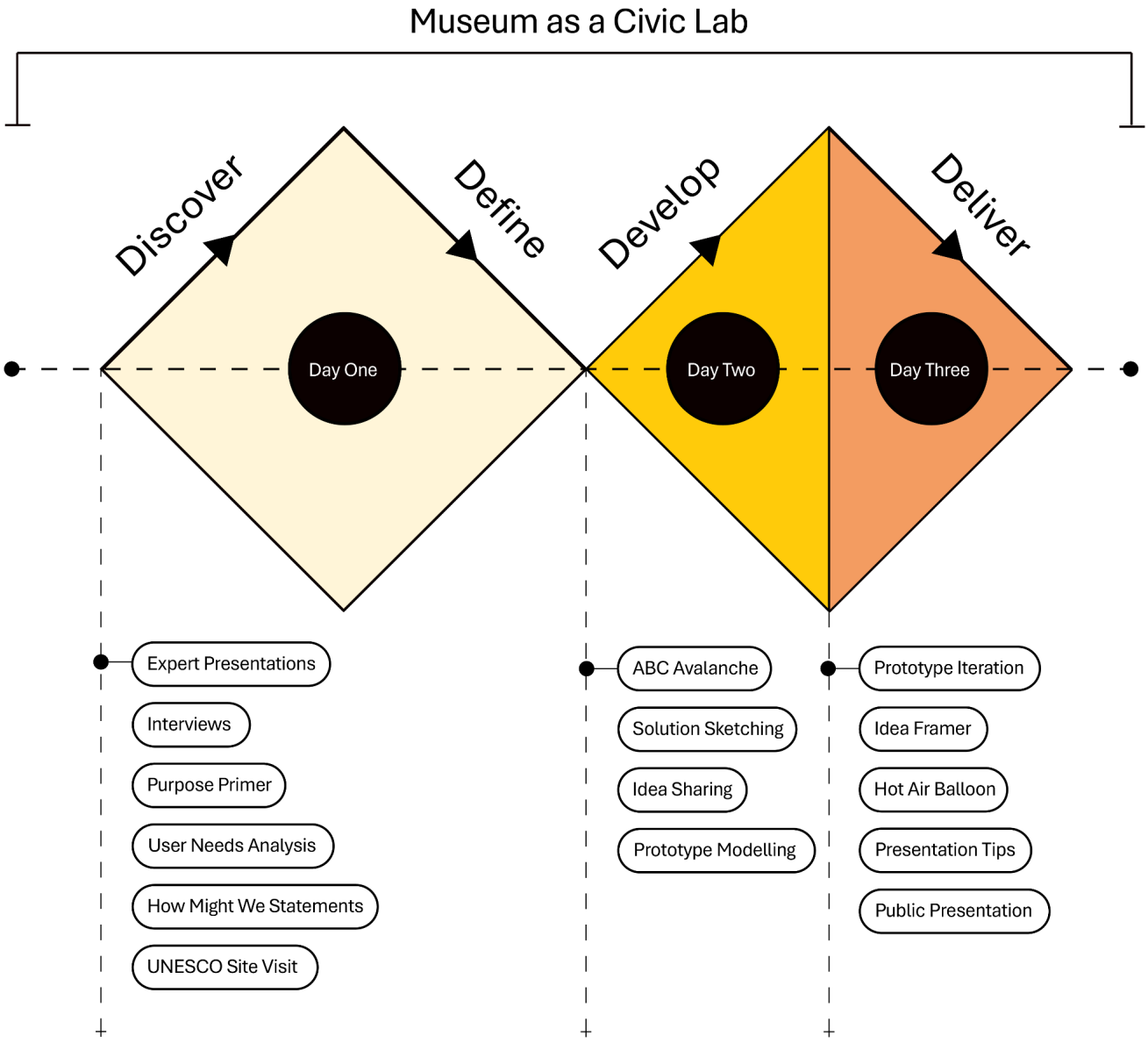

Figure 1: Methodology and Methods used in the Plastics Lab Design Sprint at V&A Dundee, structured around the Double Diamond process. Credit: Lee Johnstone

Around 25-30 undergraduate and taught postgraduate students from the University of Dundee and Abertay University worked in small interdisciplinary teams over the course of the design sprint, guided by design facilitators. Furthermore, external subject matter experts provided specialist knowledge at different stages of the process.

Each day balanced divergent and convergent thinking patterns and activities:

Day 1 – Discover/Define: student teams explored the challenge of plastic waste by employing visual mapping techniques, affinity clustering and problem analysis frameworks, while also gaining insights from expert 'lightning talks' from industry professionals and public interaction.

Day 2 – Develop: student teams generated and clustered ideas using open-source design methods like the ABC Avalanche and Nesta's Fast Idea Generator. Ideas were selected and then brought to life through sketch modelling and rapid prototyping.

Day 3 – Deliver: prototypes were further refined and later presented in poster format, sparking discussion with museum visitors.

The design brief was framed through mini-challenges that prompted the students to interrogate material, ethical, ecological, and systemic concerns. They asked: How might we design for more-than-human users? What role could bioplastics, upcycled composites, or digital transparency play in shifting perceptions of value? How might design respond to the disproportionate burden of plastic pollution on communities in the Global South while addressing local civic needs? This contextual immersion challenged and informed their design choices in real time.

Over three days, student teams developed prototypes, posters and idea framers that explored the future of plastics (see Image 3). Posters framed not only the 'what' but the 'why' of each proposal, prompting ethical, ecological, and systemic reflection. Prototyping in a live museum space also emphasized process over product with rough artefacts being used as "boundary objects" (Rhinow, Koeppen, and Meinel 2012) to spark dialogue between students and industry experts. Visitors, meanwhile, not only observed but also joined the dialogue, reinforcing the museum's role as an active site of participatory experimentation and innovation. Documentation including video, interviews, and artefacts was collected to assess pedagogic, civic, and cultural impacts.

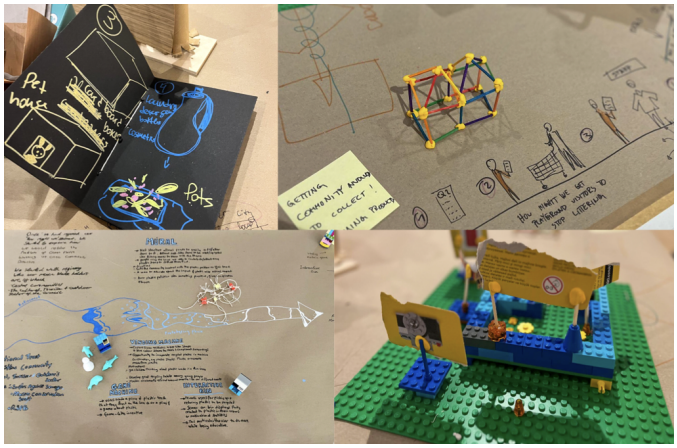

Image 3: Sample of prototypes exploring the futures of plastics.

The outputs from each team were not market-ready products but prompts and scenarios to reimagine different material futures. As discussed above, they were provocations for sparking dialogue about the role of design in the circular economy. Four speculative scenarios illustrate this range:

Plastics for more-than-human users: disposable cups that dissolve into nutrients for worms and birds, raising questions about who decides what is safe for ecosystems.

Hybrid composites: marbled building panels mixing waste plastics with hemp fibres, celebrated for durability yet contested when they begin to age and warp.

Transparent journeys: digital tags on packaging revealing full material histories, empowering some citizens while overwhelming others.

Community repair rituals: local 'Melt Nights' where broken plastics are remade into civic artefacts, blending recycling with belonging but stirring debates about whose designs are prioritized.

By reframing plastics as a site of speculation rather than solely a waste problem, the sprint highlighted design's capacity to foster critical imagination and civic engagement. These outputs contributed to the museum's ambition to act as a civic laboratory, generating artefacts, conversations, connections, and visions of what a more sustainable future might look like. Together, these provocations demonstrated design's role in opening civic dialogue, sparking critical imagination, and envisioning circular futures.

5. Learning and Evaluation

Learning and evaluation was integral to the Plastics Lab design sprint, designed to capture student experiences, public engagement, and institutional learning. Insights were gathered through surveys, observation, and informal feedback, offering a multi-layered view of outputs and outcomes. The following discussion outlines some of the key learnings identified by the students.

It was clear from the analysis that the project carried significant pedagogic value by fostering material literacy as an awareness of the properties, affordances, and consequences of different materials (cf. Ingold 2007; Karana et al. 2015). Students developed technical prototyping skills as well as the ability to articulate materials' social and ecological dimensions. It could be argued that thinking through making became a form of connecting (Gauntlett 2011) through tangible artefacts where participants linked personal creativity with broader civic responsibility. Students also gained confidence in applying speculative and participatory methods to explore ambiguous futures rather than aiming for fixed solutions.

The learning experience was also grounded in principles of experiential learning (Dewey 1938), where knowledge emerges through doing, reflecting, and adapting. Students learned to think through making, collaborate across disciplines, manage uncertainty, and communicate complex sustainability issues to non-specialist audiences. For instance, some students highlighted the challenge of working under time pressure but recognized it as a driver of creative problem-solving: "Pushing us to devise and develop new concepts in such a short space of time was challenging but timely and relevant."

Others emphasized the development of transferable skills such as teamwork and collaboration: "...it was great to learn more about how to work effectively as a part of a team and communicate successfully within a team. I also learnt a lot about the tools and frameworks that are used within design, and what goes into the creative problem-solving process, especially when generating, testing and iterating ideas...".

Other participants acknowledged the value of design-led innovation and the benefits of working across interdisciplinary boundaries: "Having a different outlook on design processes to make decision-making really fast and quick in a group and to help bring ideas forward in a really quick efficient way is what I will definitely take forward in my studies and future career." It was also noteworthy that participants recognized the broader scale and significance of the plastic crises:

"I realized that the problem is much bigger than I thought, much more complex and having the opportunity to think and work on it even on such a small scale is great."

While lightning talks from industry experts were appreciated by many of the participants, some felt they disrupted momentum for making. Others suggested that idea generation took too much of the limited time, leaving less space for physical, hands-on prototyping. There were also calls for more structured interaction with expert speakers and feedback on concepts. These observations point to the need for balancing inspiration, ideation, and hands-on making in any future iterations.

Student engagement with the museum was also enhanced. One participant noted: "It has been a really fun and informative experience. It has made me feel quite keen to explore more of what V&A Dundee has to offer."

Indeed, students requested further opportunities for talks, workshops, and activities, thereby bridging education and professional practice, especially around the topic of civic innovation for planetary health. Interestingly, one participant emphasized the synergistic relationship between the design sprint and the exhibition, observing that:

"I think that the design sprint was boosted by the Plastic Exhibition and vice versa because they are both connected in a way that the exhibition gave us insight about the problem and possible solutions, while the sprint gave us the tools to continue working as a team to find more alternative sustainable solutions."

Likewise, another student commented that: "I did really enjoy the experience, and I think the integration of the live talks and tour of the plastic exhibition with the design sprint really made it an amazing and action packed 3 days!"

For visitors, observing prototypes and engaging with posters offered a rare glimpse into the 'messiness' of design. Real-time access to collaboration and iteration demystified the design process and positioned it as an accessible civic tool for tackling complex sustainability challenges. While systematic measurement of visitor responses was limited, anecdotal evidence suggests they valued the opportunity to engage with students directly. Live making encouraged dialogue about plastics, circularity, and possible futures, extending the exhibition's impact beyond static display.

For V&A Dundee, the design sprint therefore demonstrated the potential of embedding design-led thinking and making within exhibitions. It highlighted the museum's capacity to act not only as a site of display but as an active laboratory for civic participation and innovation.

6. Scaling Beyond Education into Design Policy

Overall, it could be argued that the Plastics Lab design sprint achieved its aims of engaging students in civic design, fostering material literacy, and activating the museum as a site of experimentation. The project demonstrated how design can engage with complex material challenges not simply by reducing them to technical problems, but by foregrounding their multidimensional nature and inviting public co-authorship of possible futures. By reframing plastics not only as waste but as a site for revaluation and redesign, the sprint fostered critical engagement and creative agency among students and museum audiences alike. Prototypes became provocations, opening civic dialogue around the circular economy and positioning design as an accessible tool for long term, systemic change needed in societies. Moreover, by embedding the design sprint within *Plastic: Remaking Our World* exhibition allowed V&A Dundee to move beyond traditional exhibition-based awareness-raising toward live experimentation and civic participation.

From an education perspective, feedback from the sprint highlighted both its strengths, such as collaboration, skills development, and civic engagement as well as its limitations, including time constraints, the balance of activities, and the need for deeper expert interaction. These insights provide a foundation for refining the model and extending its application beyond education into wider civic and policy contexts. Museums, universities, and government agencies each have roles to play in creating enabling conditions for experimentation, partnership, and public participation. In this way, the Plastics Lab design sprint can be seen as both a pilot and a proof of concept. It demonstrates how cultural institutions can act as civic catalysts, advancing design education, policy engagement, and public imagination in response to the ecological crises of our time.

Future development of the Plastics Lab model should aim to extend its pedagogical and civic potential through broader institutional and policy integration. Scaling the initiative across museums and cultural institutions internationally could facilitate cross-cultural exchange and shared learning around the circular economy and climate justice, thereby positioning design as a medium for systemic inquiry rather than solely problem-solving. The establishment of future design sprints involving government, industry, and civic stakeholders would further articulate design's role as an agent of transition, supporting frameworks such as V&A Dundee's Design for Scotland: Design for... programme that aims to advance design-led approaches to public policy. Embedding these methodologies within higher education curricula would ensure that emerging designers develop critical and practical capacities for participatory and sustainable practice, integrating systems thinking into their professional formation. Moreover, creating dedicated public-facing platforms to exhibit design sprint outcomes would enable ongoing civic engagement and co-production of knowledge. In this sense, future iterations of the Plastics Lab could serve as research-in-action sites bridging design education, policy innovation, and public participation to advance the systemic transitions required for a just and circular economy.

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A Space for Design: Applying Design Methods to Enable a Circular Economy in an Evolving Space Sector

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Abstract

The space sector is rapidly becoming a backbone of the global economy, yet much of its architecture still mirrors linear, single-use models. In parallel, space agencies now signal a shift toward circular, service-led operations, including in-orbit inspection, refueling, modular upgrades, active debris removal and responsible end-of-life, underpinned by standardized interfaces and assured rendezvous and proximity operations (RPO) as enablers of In-orbit Servicing, Assembly and Manufacturing (ISAM). This paper explores how design practices like co-design, system mapping, policy prototyping and user-centred design cannot only support but actively accelerate the introduction and active adoption of circular-economy principles in that transition. A practice-informed synthesis is presented, drawing on the Satellite Applications Catapult's (SAC) user-centred and technical work and related contemporary industry literature. The analysis is organized through four lenses: (1) future targets; (2) current progress; (3) transferable lessons from circular design on Earth; and (4) near-term opportunities for design. Findings highlight recurring gaps within stakeholder practices, interoperability and assurance hurdles, and weak user/market definition, alongside emerging solutions and changing sectoral priorities. The paper proposes a high-level Design enabled Circular Economy (CE) view for in-orbit systems and distils design interventions that convert principles into practice: co-creation of interface standards; service blueprints for ISAM (inspect, refuel, tug, upgrade, end-of-life); policy and procurement patterns that reward lifecycle outcomes; and assurance artefacts for regulators and insurers. Illustrative activities include the SAC's User-Centred Design (UCD) teams' activities in supporting this emerging area of activity, industry case studies, and recommendations for future design sector involvement. This paper's contribution to design research is a foundational, design-centred pathway to space sector engagement, that links standards, services and incentives, with the aim to make circularity in orbit practical, safe and sustainably scalable.

Keywords: Circular economy, design policy, in-orbit servicing, space sustainability, systems thinking.

1. Introduction

Our understanding of the circular economy has traditionally adopted a bird's-eye view, observing human activity from above, assessing the environmental consequences of industrial processes and end-of-life outcomes, and charting pathways toward more sustainable systems. Yet today, the sky is no longer the limit to our environmental bubble. Satellite technologies have become vital tools for navigation, supply chain logistics, communication, and environmental monitoring. As we shift our gaze upward, it becomes clear that the space sector, now a cornerstone of technological and economic infrastructure, is replicating terrestrial industrial patterns of disposability and resource inefficiency.

In the UK, satellite services support approximately 18% of the UK's national GDP (Hagelberg et al. 2025), with industries across energy, logistics, agriculture, as well as the broad range of the digital products and services we encounter daily are reliant on space-enabled systems. A disruption to satellite navigation systems alone could result in economic losses exceeding £7.6 billion over just seven days (Flytkjær et al. 2023; UK Space Agency 2024). However, this dependency underpins a growing challenge: the security and environmental footprint of orbital operations. As of April 2025, an estimated 12 000 active satellites orbit the Earth, with projections anticipating between 60 000 and 100 000 by 2030 (ESA 2025; Strategy And 2023; NSOC 2024).

Much like the accumulation of plastics in our oceans, approximately 54 000 objects larger than 10 cm, 1.2 million catalogued fragments exceeding 1 cm (untracked), and an estimated 130 million objects between 1.mm-1cm are currently in Earth orbit (ESA Space Debris Office 2025). This expanding debris field threatens the safety of future missions and the long-term viability of space-based economic activity which in turn endangers much of the planet's growing digital and electronic sectors.

Beyond the issue of debris, the design lifecycle of in-orbit assets contributes further to environmental degradation. A circular economy's (CE) aim is to eliminate waste and pollution, circulate products and materials at their highest value, and regenerate natural systems. Applied to space, this translates into designing systems, platforms and services for maintenance, reuse, repair, refurbishment, remanufacture and repurpose, with recycling or responsible re-entry when higher-value loops are not feasible (Ellen MacArthur Foundation 2025; European Space Agency 2025a; Caiazzo and Turner 2024).

While circular principles are increasingly applied to reduce the lifecycle impacts of terrestrial products, space systems continue to follow a linear model. Many satellites remain single use, designed without the incorporation of CE systems, and are ultimately incinerated during re-entry or discarded in the 'Point Nemo' ocean graveyard. (ESA 2024a; Caiazzo and Turner 2024). While it is notable that the deorbit of smaller craft typically lead to their complete incineration, all deorbits lead to atmospheric or aquatic contamination from chemical and in rare cases radiological pollution (Lampkin and Wyatt 2023; European Space Agency 2024b). When considering the manufacture, launch, Life in Service (LiS), and disposal of space systems, there are no stages of the existing lifecycles that could not be considered harmful to our environment.

Over the past three decades, the design community has undergone a necessary awakening, confronting its role in consumer culture and working to overcome the limitations of unsustainable practices. While our collective learning continues, designers can leverage methods, systems mapping, facilitation, creative problem-solving, that they have been applying in other sectors and which uniquely position designers to challenge existing practices and collaborate with space organizations to alter the status quo and catalyze change.

While it is often stated that the impact of a system is determined at the design stage, the design stage no longer resides at a single point of a product or systems life cycle. It needs to be recognized that everything is designed. A transition to circularity is therefore a systemic task, spanning architecture, interfaces and standards; procurement and licensing; operational services (e.g., inspection, refueling, modular upgrades, end-of-life shepherding); data and assurance; and finance and insurance. Design disciplines, including service design, industrial/systems design, user-centred and UI/UX design, policy design, and speculative futures, are well placed to contribute. Each design discipline offers unique and valuable research approaches, combined with an array of business, service and product implementation expertise, key to the next phase of in orbit operations. They offer methods to map complex ecosystems; co-create interoperable interfaces; blueprint operational services; prototype user journeys and decision tools; and develop policy and procurement patterns that reward lifecycle outcomes.

Papanek (1985) observed that designers act as bridges and interpreters between specialized communities, a role that is directly applicable to the multi-actor realities of space programmes. Designers occupy a unique position, applying expertise from a range of fields to enable their research and practical delivery activities, focused on addressing the problem with the right solution. In convening intersectoral collaboration designers contribute their expertise to development, while acting as developmental catalysts uniting stakeholders to communicate clear stories that align engineering, commercial, regulatory and end user outcomes.

Image 1: Many space agencies now signal a shift toward circular, service-led operations, including in-orbit inspection, refueling, modular upgrades, active debris removal and responsible end-of-life. Credit: Catapult Open

2. Methodological Approach

This paper addresses the question: where, and how, can designers support the acceleration of the implementation of an in orbit circular economy?

To keep the analysis focused and comparable, the discussion has been presented through four lenses:

1. Future targets;
2. Current progress;
3. Circular design expertise and transferable lessons from terrestrial practice;
4. Lessons from practice and possible future contributions from the design sector.

This paper presents a practice-informed analysis, conducted by service designers currently working within the space sector. The work draws on the evolving knowledge and practices of the Satellite Applications Catapult's User-Centred Design (UCD) and technical teams, combined with targeted literature to situate practice within wider sector trends.

2.1. Sources and Curation

Related internal projects were reviewed and selected from 2023–2025, alongside grey literature (policy briefs, standards drafts, accelerator evaluations) and public reports. Materials have been included where they (a) relate directly to circularity, operational services or In-Orbit Servicing, Assembly and Manufacturing (ISAM), (b) contained explicit assumptions or decisions relevant to lifecycle outcomes, or (c) illustrated barriers or enablers for serviceability, interoperability and adoption.

2.2. Synthesis

A lightweight, practice-led synthesis was used:

Gather: Curated internal artefacts (service blueprints, systems maps, workshop notes, concept papers) plus selected public/grey sources relevant to in orbit circularity.

Frame (foundational): Set out a basic organizing framework, key actors, the interfaces between them, core service types (inspection, refueling, upgrade, end-of-life), and the enabling conditions (standards, policy, assurance, value streams).

Review and refine: The research and draft framework was reviewed by the UCD and technical teams. Colleagues provided amendments and advice based on sector expertise, clarified terminology, and highlighted recurring issues (e.g., early lock-in, interoperability gaps, assurance needs, weak user/value fit).

Synthesis and reflection: Converted convergent themes into actionable patterns and questions (where design can intervene; what evidence or standards are missing) and captured open assumptions for future validation.

2.3. Positioning and Limitations

The intent of this analysis is to generate suggestions for actionable engagements/collaborations between the design and space sectors, illustrated by circular-economy life cycle illustrations for in-orbit systems and realistic business and technology developments. Findings reflect SAC's practice context and are qualitative in nature. The corpus is selective and includes non-peer-reviewed artefacts. The author therefore presents the synthesis as decision support for near-term strategy, design and policy work, and as a basis for further enquiry (including quantitative modelling, standards sandboxing and live trials of operational services).

3. Findings: Themes from Practice

3.1. Target Futures

Sustainability and the circular economy now feature widely across international forums, yet delivery remains difficult. In space, most missions still follow a linear model (See Figure 1 for a simplified lifecycle view of impacts and end-of-life pathways), although leading organizations are aware of the need for the integration of more sustainable practices, and are signaling a shift toward service-led and interoperable operations. The European Space Agency (ESA) has set a long-term ambition to establish a circular economy in orbit by 2050, to safeguard the long-term viability of in orbit activities in an increasingly congested orbital environment (European Space Agency 2025a; European Space Agency Space Debris Office 2025; Caiazzo and Turner 2024).

This future is commonly framed around three connected capability sets:

Life-extension services: refuel, inspect/repair, upgrade/refurbish and otherwise maintain assets in orbit, including controlled navigation takeover to enable servicing or safe disposal.

Risk-reduction services: active debris removal (ADR) and end-of-life shepherding to reduce collision risk and free-up capacity for new operations.

Materials and manufacture: in-orbit manufacturing and recycling to reduce launch dependence and keep materials in circulation.

A further enabler sits across all three capabilities, standardization and interoperability, incorporating (mechanical/electrical/data interfaces, procedures and telemetry) so mixed fleets can be safely serviced by third parties.

Today, the majority of launched mass (e.g., spent fuel, expended stages and fairings) is discarded within hours of launch, contributing to atmospheric and ocean pollution; on-orbit failures or fragmentation events create debris that remains in orbit and can persist for hundreds to thousands of years. In extremely rare cases, debris that has not burnt up during de-orbit can fall to land (Garcia 2024; European Space Agency 2025b; 2024b).

ESA (2025b) vision looks beyond mitigation to designing out debris creation, removing legacy debris, and re-circulating materials, targeting scenarios where a significant proportion of mass placed in orbit is reused, upgraded or recycled, and where atmospheric impacts across the supply chain are progressively neutralized (European Space Agency 2025b). To move in this direction, ESA is advancing EcoDesign and Zero Debris policies and encouraging the use of life-cycle assessment (LCA) during mission and technology development. Practices long discussed and utilized in consumer product production. These capabilities are not only technical; they require service models, common interfaces and assurance, which are core design challenges.

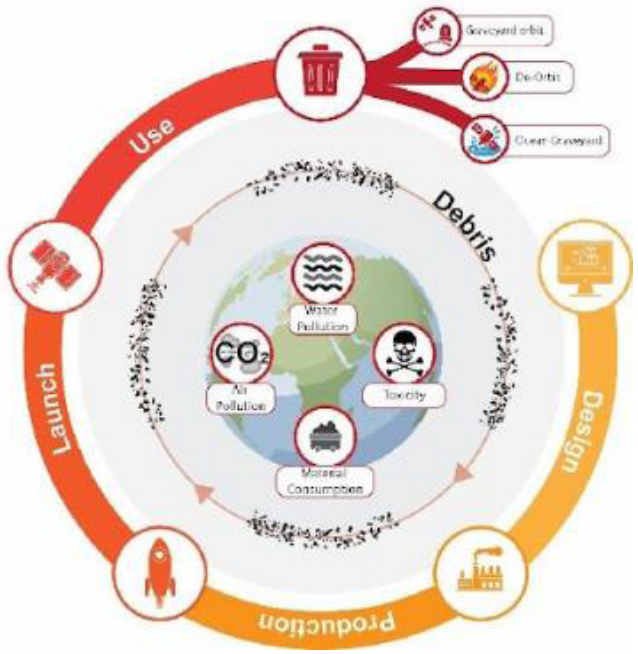

Figure 1: Image adapted from the diagram presented by ESA (2020), edited to incorporate additional end of life outcomes. The diagram shows the current life cycle of a space craft.

Key areas of the future include the ability to repurpose and recycle materials in orbit, reusable launch systems (Space X, Falcon 9 and Starship are early examples) and standardized interfaces and interoperability. By developing these systems, there is the possibility of phased or upgradable assets, reducing the burden on the environment while simultaneously reducing the burden on companies trying to build and deploy full systems and capabilities at one time.

3.2. Progress in Motion: How the Sector is Already Moving Toward Circularity

Public signals indicating the need for sustainable action have also come from beyond the space community. In 2021, the Terra Carta set out a cross-sector compact for climate, nature and people, inviting industry to align innovation, investment and governance with long-term planetary health (Sustainable Markets Initiative 2021). It has acted as a rallying point, via initiatives such as the Terra Carta Design Lab, for translating high-level principles into practical action and solution creation. In 2023, the Astra Carta extended this intent to space, calling for stewardship of the orbital environment, international cooperation and market incentives that reward responsible practice (Sustainable Markets Initiative 2023). Read together, they legitimize a shift from single-use missions to circular, service-led operations, and place the private sector alongside agencies and standards bodies, calling for real co-developed change. The charters set the tone and ethical guidelines for future actions, but they are by no means operating manuals. Designers can translate principles into standards, service patterns, assurance artefacts and procurement language that organizations can adopt, adapt and apply.

3.2.1. Policy Signals that are Shaping Behaviour

- **ESA Zero Debris**: ESA has set a direction for debris-neutral missions and is building a coalition of public and private signatories (European Space Agency 2024a; 2025b). It pushes disposal and risk-reduction from 'nice to have' into programme design.
- **Post-mission disposal rules**: in the US, the Federal Communications Commission (FCC) '5-year rule' for low earth orbit (LEO) is already tightening end-of-life planning, requiring that satellites in low earth orbit must deorbit and burn up in the atmosphere within five years of the completion of their mission (Federal Communications Commission 2022). While this supports the reduction of in orbit debris and congestion, it poses a risk to the increase of atmospheric pollution.

3.2.2. Standards and Guidance that Enable Safe Servicing

- **ISO 24330:2022 – RPO/OOS Guidance**: establishes high-level principles for rendezvous, proximity operations and on-orbit servicing, foundations for interoperability and insurance/assurance discussions (ISO 2022).
- **CONFERS best practice**: an industry consortium publishing recommended design and operational practices for servicing (capture features, relative navigation behaviours, info-sharing) (CONFERS 2025).

3.2.3. Demonstrations proving circular services are viable

- **Life-extension in GEO**: Northrop Grumman's Mission Extension Vehicles (MEV-1/2) docked with ageing GEO satellites to provide station-keeping, adding years of service life and deferring replacement (SpaceLogistics 2021).
- **Debris risk reduction**: Astroscale Japan's ADRAS-J, under JAXA's CRD2 programme, is demonstrating non-cooperative rendezvous/inspection of a derelict upper stage groundwork for future active debris removal (JAXA 2024).
- **Refueling infrastructure**: Orbit Fab's RAFTI port (open license) is baselined on numerous missions (incl. USSF/DoD), suggesting early alignment on storable-propellant transfer interfaces supporting the development of common refueling interfaces (Orbit Fab 2025).

3.2.4. Tools that Move Impact Upstream

- **EcoDesign & LCA**: ESA provides EcoDesign guidance and an LCA database, nudging teams to consider whole-life impacts (materials, production, launch, operations, disposal) during early trade offs (European Space Agency (ESA) 2021).

3.2.5. What this Adds Up to (and Where Design Fits)

Taken together, these strands form a coherent trajectory. The Terra Carta and Astra Carta set the intent and invite cross-sector action; policies such as Zero Debris and the FCC five-year rule convert that intent into real constraints and incentives; ISO 24330 and CONFERS supply a shared language for safe servicing; and demonstrations like MEV, ADRAS-J, and RAFTI show that life extension, inspection/ADR and refuelling are technically and commercially credible. Alongside this, EcoDesign and LCA bring environmental choices into view early, where they can shape decisions. Within each isolated example, what remains is largely design work: turning principles into things teams can adopt, codified interfaces, service blueprints, assurance evidence, and policy/procurement patterns, so circular operations become not only possible, but practical and investable for operators, regulators, insurers and investors alike. While these signal positive steps towards circular economy in space, there is still debate among sectoral leaders about which standards and practices should be adopted, with some stakeholders demonstrating a resistance to change. Much as has often been seen in the commercial manufacturing environment, the 'but we've always done it this way' mindset is still prevalent in a sector highly reliant on legacy systems.

3.3. What Design Brings: Lessons from Earth for Circularity in Orbit

Design has a proven record of turning sustainability principles into workable systems: products that can be repaired and upgraded, services that keep assets in use, and policies and procurement that reward better lifecycle outcomes. Classic treatments position designers as bridges and interpreters between specialist communities (Papanek 1985), an ability that is becoming increasingly relevant to multi-actor space programmes. The circular economy itself is framed around designing out waste, circulating products and materials at their highest value, and regenerating natural systems, an agenda designers have helped operationalize across sectors (EMF 2025).

Below, each enabler of an in-orbit circular economy is linked to terrestrial precedents where design has made similar shifts possible, with brief notes on what to transfer.

3.3.1. Interoperability and Standards (The Precondition for Services)

Without shared mechanical/electrical/data interfaces, third-party servicing (inspection, refueling, upgrades, end-of-life shepherding) cannot scale.

What design has done on Earth:

- **The EU's move to USB-C** as a common charging standard shows how interface convergence, backed by policy, simplifies user experience and reduces waste (Directorate-General for Communication 2024).

These examples demonstrate how convening cross sectoral partners and regulators can lead to agreed shared interfaces. The same approaches could be applied to co-create 'space-USB' style reference ports for docking/refueling/health data, with technical specifications, interaction steps, and failure-mode playbooks that different manufacturers can adopt without bespoke engineering.

3.3.2. Serviceability by Design (Access, Modules, Documentation)

Life extension of in orbit assets depends on the ability to reach, remove and replace parts safely, often by robots, under tight time and risk constraints.

What design has done on Earth:

- **Modular laptops (Dell Concept Luna + Framework)**: easy to open, easy to upgrade. Taken together, Dell's Concept Luna and the Framework Laptop show how mainstream computing can be designed for quick access, modular repair and upgrades, and long service life. Luna is Dell's research platform exploring fewer fasteners, snap-fit parts, clear component access, and end-of-life recovery, so repairs are faster and materials are easier to reclaim (Dell Technologies 2023). Framework turns the idea into a commercial, fully modular notebook: ports, storage, memory, keyboards, and even the mainboard, are user-replaceable, with openly available parts and guides plus a marketplace for upgrades (Framework Computer Inc. 2025).
- **Fairphone (Gen 6)**: A consumer smartphone built for repair and longevity, enabled by modular replaceable battery, camera and ports, spare parts, clear repair guides, and long software support. The business model rewards keeping devices in service for longer, and exemplifies how modular electronics designed for longer life cycles can be enabled by careful service and system modelling for sustainable ecological and economical impact (Fairphone 2025).

Design's role is to make things easy to reach, easy to swap, and easy to prove safe. For satellites, that means agreeing common ways to attach and connect parts, leaving clear access for servicing, using recognizable fasteners/connection points, and providing simple, step-by-step guides (the space equivalent of a repair manual) that humans or robots can follow. If spacecraft are built this way from the start, in-orbit servicing and manufacturing (ISAM) teams can inspect, refuel, upgrade or retire assets without replacing the whole vehicle. That's the core of circularity in orbit: designing for repair and upgrade.

3.3.3. Service Models, Assurance and Finance

Operators, regulators, insurers and investors need clear service level agreements (SLA), liability hand-offs, telemetry and test evidence to underwrite new services.

What design has done on Earth:

- **Rolls-Royce TotalCare** shows how a highly engineered product becomes a usable, bankable service. The technology (engines, sensors, analytics) only works at scale because design shaped the value proposition, the customer journey (plan → monitor → bill), the dashboards teams rely on, and the contracts/SLAs that align risk and reward. In short, design turned capability into something airlines can buy, operate and underwrite (Rolls-Royce plc. 2017).

Adoption hinges on clear, step-by-step playbooks for the five core ISAM services, inspection, refueling, tug/relocation, upgrade and end-of-life stating who does what, when, and how hand-offs and success are judged. Each playbook also sets out the data shared before, during and after operations, with simple go/no-go checks. Matching assurance packs minimum telemetry, operator authorizations, standard task cards and release records bring the service into line with licensing and insurance expectations, as in aviation and availability-based models.

3.3.4. Reverse flows and materials recovery

Circularity requires return paths, either for on-orbit reuse/recycling, or verified, responsible re-entry and material recovery.

What design has done on Earth

- **Interface** carpet tiles use design for disassembly, serialization and take-back to enable remanufacture and recycling at scale (Interface 2025).
- **Managed print services** (e.g. Xerox/HP) combine service contracts with remanufacture of consumables and parts, proving the business logic of closed loops (Shull 2023).

By enabling reverse flows through materials tracking and take-back: serialized components, consolidated hardware on-orbit for reuse/recycling, and verified re-entry evidence. With this traceability, impacts and recovered value are measurable, so procurement can reward serviceability, responsible end-of-life (EOL) and materials recovery.

3.3.5. Closing the Adoption Gap (Users, Markets, Workflows)

Many ventures start solution-first and struggle to fit into operator workflows or to show return on investment (ROI). Public evaluations of the UK Space Agency Accelerator show targeted customer discovery support substantially improves customer definition, competitor understanding and clarity of market opportunity (Know.Space 2025). While not a design programme, the Accelerator's customer-discovery and proposition-testing components are consistent with user-centred design methods (research, value-proposition iteration, service modeling) and could be advanced by the incorporation of design methodologies.

3.3.6. Lessons from Practice and Possible Future Contributions from the Design Sector

Space solutions require significant investment to implement, operate and scale. To unlock that capital, organizations must de-risk decisions by evidencing clear user value, workflow fit and credible routes to revenue. Recent UK reviews highlight recurring barriers: unconvincing business cases/ROI, weak demonstration of benefits in end-user contexts, and limited understanding of customer challenges, often resulting in siloed offerings (UK Space Agency 2025). Complementary evidence shows that targeted support can materially improve market readiness: within the UK Space Agency Accelerator, ventures reporting the ability to identify target customers rose from 75% to 96%, competitor understanding from 78% to 98%, and market-opportunity clarity from 55% to 82% (Know.Space 2025). In short: many teams are solution-led; design closes the adoption gap.

3.3.7. The Catapult's User-centred Design Contribution

The designers at the SAC are working in a new sectoral frontier (some may say the final frontier), in which a new era of industrial revolution is being formed. The SAC's User-Centred Design (UCD) team acts as a sector convenor and translator between engineering, policy and markets. The team applies user-centred, service, industrial/systems and policy design to make complex capabilities usable, safe and investable. The following examples provide just a small sample of the of the practical applications of service design methods being utilized in the space sector:

- **Regulation and assurance**: in the UK, RPO Regulatory Sandbox (Stage 1), the UCD team's contribution was user-requirement capture through design: they applied service-design research to structure inputs from consortium stakeholder workshops and the iterative mock-licensing prototype of the Target Mission Concept (TMC); used journey mapping and scenario modelling to make licensing, operations and assurance pathways visible; and practiced information/interaction design to organize the Sandbox MVP, namely the TMC, a tailored Technical Question Set (TQS) and simulation inputs, so that requirements, evidence needs and decision points were clear to regulators and operators. They also synthesized feedback from wider-industry sessions (including Catapult-led workshops) into the published challenges and actionable recommendations that inform future guidance (Astroscale Ltd et al. 2025).
- **Capability development**: at the Enabling Serviceable Spacecraft Design SPARK workshop (February 2025, Space Park Leicester), delivered with design-led facilitation (double-diamond; challenge mapping → How might we → speculative road-mapping), the UCD team applied service-design methods for user-requirement capture. They synthesized inputs from operators, primes, agencies and cluster partners into a prioritized set of interface-related needs (mechanical/electrical/data interconnects and servicing features), staged demonstration roadmaps (near-/mid-/long-term) and a structured issues log (standardization gaps, business-model/insurance considerations, regulatory alignment). Tangible artefacts: prioritized interface-needs list, demo-pathway sketches, and an adoption-barriers register. At the beginning of the session there was significant speculation from the stakeholders about changing legacy practices, however after running through the session's activities and road mapping possible future technology developments and services, there was a marked increase in optimism and interest in the feasibility of serviceable spacecraft.
- **Adoption and growth**: through the Space Commercialization Engine (SCE), the UCD team delivers tailored 1:1 design support session. They support developing organizations by conducting stakeholder interviews, drafting value-proposition statements, creating service model canvases, and building technology/business/service roadmaps. Where relevant, the team also convenes roundtables (e.g., biodiversity applications) and issues actionable session reports to align partners and accelerate market fit. These sessions deliver more than a traditional accelerator programme by supporting in depth understanding of the organizations end user and service models. These realizations allow for better organizational planning, more attractive investment opportunities and more relevant and impactful service offerings.

3.3.8. Opportunities for the Application of Design Methodologies (Near-term Priorities)

1. Interoperability and interfaces: co-create reference docking/refueling/data ports and task flows ('space-USB' style), plus fit-check tools and failure-mode playbooks to reduce integration cost and risk.
2. ISAM service blueprints: publish blueprints for inspect, refuel, tug, upgrade and end-of-life shepherding, showing customer journeys, backstage processes, data schemas, safety interlocks and liability hand-offs.
3. Assurance artifacts: demonstrate considerations and actions that derisk the life cycle and service being implemented in alignment with licensing and underwriting requirements.
4. Impact metrics and storytelling: agree simple measures (years-of-service extended; launches averted; verified EOL rate; % fleet serviceable) and use clear narratives to build legitimacy for ADR, refueling and upgrades.

By pairing the Catapult's convening role with a service-oriented design process for uptake, the sector can move from intent to implementation, turning standards into usable interfaces, capabilities into services, and circularity into something practical, safe and investable.

4. Discussion: Making Circularity Practical, Safe and Investable

The findings point to a clear conclusion: progress toward an in-orbit circular economy will stand or fall on the co-evolution of interfaces, services and incentives. Technical capability alone is insufficient. Operators, regulators, insurers and investors need shared standards, service models they can procure and underwrite, and evidence that links design choices to operational and environmental outcomes. Design's value lies in turning these dependencies into workable patterns.

Three tensions must be managed.

1. **Standardization vs. innovation**: reference interfaces for docking, refueling and data are essential for third-party servicing, yet premature lock-in can constrain future architectures. A design-led approach can stage standardization: publish minimum viable interface patterns and adoption toolkits now, while maintaining extension points and versioning to protect innovation.
2. **Safety, assurance and openness**: servicing depends on clear behaviours (approach corridors, handshakes, abort paths) and verifiable data sharing. At the same time, operators are cautious about exposing proprietary information. Here, policy design and service blueprinting can define role-based data schemas, evidence thresholds and liability hand-offs that satisfy licensing and underwriting without oversharing.
3. **Near-term cost vs. long-term value**: serviceable designs, interface compliance and assurance packs add work up front; the returns arrive through extended life, avoided launches and reduced collision risk. Design can close this gap by expressing lifecycle value in stakeholder-specific terms (operator OPEX/CAPEX, regulator risk reduction, insurer loss-prevention), and by packaging pilot pathways that de-risk first adoption.

A further risk is burden-shifting: solving on-orbit problems by externalizing impacts to the atmosphere or oceans at end-of-life. Integrating EcoDesign/LCA prompts into early trade-offs and linking them to verified re-entry practices helps teams avoid unintended consequences while evidence matures.

The work also highlighted a disciplinary boundary that needs careful handling: systems engineering is the professional practice responsible for spacecraft integration. Donnella Medows defines a system as "an interconnected set of elements that is coherently organized in a way that achieves something" (Meadows 2008), while systems thinking adopts a way of thinking that helps us identify root causes of problems and see new opportunities by relating system structure to behaviour (Hacking 2025). Framed well, these are mutually reinforcing. Design should not duplicate engineering authority; it should make the whole operating model legible and applicable to real world challenges.

Finally, adoption remains the persistent bottleneck. Public evaluations show many ventures are solution-led and under-specified on customers, workflows and routes to market. The Catapult's UCD activity, including the serviceable-spacecraft workshop and Space Commercialization Engine, demonstrates a repeatable design-for-adoption process that can be applied to circular operations: co-create interfaces, blueprint services, define assurance artefacts, and prepare policy/procurement patterns that reward lifecycle outcomes.

In summary, the transition to circularity is less a single technical leap than a programme of design work: codifying interoperable interfaces; making services procurable and safe; and aligning incentives across policy, finance and assurance. With a neutral convening role and practice-tested methods, the design community, and specifically the Catapult, can help the sector move from intent to implementation at pace.

5. Implications and Recommendations

Implication 1: interfaces unlock services. Circularity in orbit depends on interoperable docking/refueling/data ports and clear operating behaviours.

> **Recommendation**: launch a pre-competitive Interface Working Group (operators, primes, agencies, insurers) to publish reference ports and RPO task patterns with versioning and fit-check tools.

Implication 2: services must be procurable and under writable. New ISAM capabilities stall without explicit operating models, liability paths and data expectations.

> **Recommendation**: publish service blueprints for five core services (inspect, refuel, tug, upgrade, end-of-life) including SLAs, decision gates, abort paths, telemetry schemas and hand-offs.

Implication 3: assurance needs evidence, not aspiration. Regulators and insurers require verifiable behaviours and test records.

> **Recommendation**: co-design assurance artefacts: minimum telemetry sets, operator authorizations, standard test cards, and configuration/serialization tags linked to licensing.

Implication 4: policy and procurement shape the market. Lifecycle outcomes improve when incentives are aligned.

> **Recommendation**: prototype license annexes for safe RPO/data-sharing and introduce lifecycle-weighted procurement that rewards serviceability, verified end-of-life and debris-risk reduction.

Implication 5: market adoption of new solutions and service can become bottlenecks. Many propositions are solution-first and weak on user/market fit.

> **Recommendation**: deploy a repeatable UCD processes easily applied by space sector organizations (as in SCE): user research, value-proposition testing, service canvases, staged roadmaps, and multi-party roundtables to ensure user requirements and market demand are met.

Implication 6: avoid burden-shifting. On-orbit fixes must not externalize impacts to atmosphere or oceans.

> **Recommendation**: embed EcoDesign/LCA prompts in concept reviews, business plans and service models; pair end-of-life choices with evidence plans for re-entry effects and materials pathways.

Implication 7: capability and inclusive knowledge sharing. Skills and access gaps will slow innovation and ecosystem growth.

> **Recommendation**: create short training modules (serviceability by design; safe RPO basics), shared pattern libraries, and on-ramps for SMEs and emerging space nations.

Who does what, at a glance:

- Industry/operators: adopt reference interfaces; pilot two service blueprints; publish telemetry subsets for assurance.
- Agencies/regulators: run standards sandboxes; test license annexes; align funding with lifecycle-weighted criteria.
- Investors/insurers: co-define risk questions tied to interfaces/assurance packs; support staged demo pathways.
- Design community (e.g. Catapult + partners): convene working groups; maintain pattern libraries; lead service blueprinting and adoption support.

Net effect: standards + services + incentives move together, making circular operations practical, safe and financially feasible.

What each design discipline can contribute (preview):

- Industrial/systems design: serviceable architectures; standard ports; module boundaries; diagnosability; human–robot task design.
- Service design: operating models and SLAs for inspect/refuel/tug/upgrade/EOL; ground–space hand-offs; incident/abort procedures.
- User-centred design: workflow research; console and interaction design; trials with operators, regulators and insurers; adoption and training.
- Policy/procurement design: model license annexes (RPO data/telemetry, safe capture), lifecycle-weighted tenders that reward serviceability and verified end-of-life.
- Futures/speculative design: scenario rehearsals to test timing, standards pathways and market models before hard lock-in.
- Facilitation and storytelling: visual systems maps, standards sprints, and public-facing narratives that build legitimacy for ADR, refueling and upgrades.

Taken together, these precedents show that circularity is not only a technical problem; it is a designable system of interfaces, services and incentives. The next section details how these contributions can be organized for the space sector.

6. Limitations and Future Work

This paper presents a practice-informed synthesis based on internal artefacts, selected grey literature, and public reports. It is qualitative and selective, and not a protocol-driven systematic review. Some materials are non-peer-reviewed practice documents, and several examples may be UK-centred. Given the pace of change in technology, markets and regulation, specific details discussed in this document may rapidly evolve.

Future work to deepen and operationalize these findings:

- **Quantitative validation**: pair design insights with cost–benefit and lifecycle modelling (e.g., value of serviceability, avoided launches, collision-risk reduction from standards adoption).
- **Live trials of core services**: conduct operational pilots incorporating design method into their development process for inspect, refuel, tug/relocate, upgrade and end-of-life shepherding, with defined SLAs, telemetry sets, safety interlocks and evidence packs for licensing and underwriting.
- **Environmental pathways**: extend LCA to cover re-entry/atmospheric effects and scope materials recovery (on-orbit consolidation, verified re-entry) alongside governance and verification mechanisms. Furthermore, incorporating service derived environmental factors which may alter the traditional life in service of the spacecraft.
- **Policy & procurement prototypes**: co-design license annexes (RPO data-sharing, safe capture procedures) and lifecycle-weighted procurement that rewards serviceability and verified end-of-life.
- **Longitudinal evidence**: establish multi-year case studies tracking metrics such as years-of-service extended, launches averted, verified EOL rate, and interface adoption.
- **Designed forums and tools**: have design teams shape the venues and artefacts for alignment (working groups, playbooks, decision guides, pattern libraries) so outputs are usable by operators, regulators, investors and insurers.

Together, modeling, field trials, standards maturation and designed forums will convert promising patterns into repeatable practices for a circular, service-led space economy.

7. Conclusion

This paper set out to examine where, and how, design can accelerate the implementation of an in-orbit circular economy. It has done so by (i) clarifying the target future (service-led, interoperable operations), (ii) summarizing current progress (policy signals, early standards and demonstrations), (iii) translating terrestrial circular-economy precedents into the space context, and (iv) proposing near-term, design-led interventions that make circularity practical, low risk and financially viable.

The principal contribution to design scholarship is a foundational framework for design practice to operationalize circular-economy principles in a frontier domain. Specifically, the paper:

- Articulates a design-for-adoption process (from user research and value propositions to service blueprints, interface patterns and assurance artefacts).
- Maps the co-dependencies between interfaces, services and incentives, showing how design can convene engineering, policy and finance around workable patterns.
- Identifies discipline-specific roles (industrial/systems, service, user-centred, policy/procurement, futures) aligned to ISAM/RPO needs.

Practically, the recommendations provide actionable starting points: pre-competitive interface work, ISAM service blueprints, assurance packs, lifecycle-weighted procurement and standards sandboxes. The approach is practice-informed and qualitative, and future work should add quantitative validation and live operational trials; nevertheless, it offers a clear pathway for design teams and space actors to move from principle to implementation.

In short, the paper advances a design-ready agenda for circularity in orbit, linking standards, services and incentives, so that sustainable space operations become more adoptable at scale.

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Speculative Healthcare: Envisioning a Climate-resilient NHS Scotland Through Design Fiction

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Abstract

This research addresses the climate emergency and its systemic implications for public health by employing speculative design to examine pathways towards a climate-resilient NHS Scotland in 2048, its centenary year. Developed in partnership between the University of Dundee, Heriot-Watt University, V&A Dundee, and Studio Andthen, this paper presents *Circulate*, research within a larger project for *Design HOPES* (Healthy Organizations in a Place-based Ecosystem, Scotland), an AHRC-funded Green Transition Ecosystem Hub within the Design Museum's Future Observatory. The paper focuses on *Circulate*, a design-led research project that mobilizes speculative design as both method and medium. Centred on a design-led board game, *Circulate* uses speculative scenarios to interrogate the entanglements of healthcare provision and circular innovation. The game, co-designed with Studio Andthen, provides a structured participatory framework through which stakeholders engage with plausible climate futures, negotiate systemic constraints, and prototype adaptive healthcare innovations and ideas. Methodologically, the project advances speculative design by embedding it within a participatory, game-based format that functions as a site for anticipatory governance and cross-sector dialogue. Conceptually, it situates speculative artefacts as mediating devices that translate abstract sustainability imperatives into situated imaginaries with practical relevance for a broad range of key stakeholders and the public. The findings indicate that speculative, game-based methods can generate novel insights into organizational resilience, expose tensions within existing health infrastructures, and foreground alternative trajectories under conditions of ecological uncertainty. By positioning speculative design as a critical tool for collective sense-making and strategic foresight, *Circulate* contributes to emerging debates on how design research can support health systems navigating climate transition.

Keywords: Circular economy, climate resilience, design fiction, design futures, participatory design, NHS Scotland, speculative design, systems thinking, sustainable healthcare.

1. Introduction

The climate emergency represents one of the most profound and complex challenges of the twenty-first century, with implications spanning ecological, social, economic, and institutional domains. Healthcare systems sit at the centre of these pressures. Beyond the direct health impacts of environmental change ranging from heat stress and respiratory illness to the spread of infectious disease, climate disruption exacerbates systemic vulnerabilities, strains infrastructures, and deepens inequalities in access to care (Watts et al. 2021). For national health systems already under pressure from demographic change, technological shifts, and financial constraints, the climate crisis demands more than incremental adaptation. It calls for a fundamental rethinking of how healthcare is conceived, delivered, and sustained within planetary limits.

At the heart of this rethinking lies the question of material flows. Healthcare is materially intensive: hospitals, clinics, and supply chains rely on a continuous throughput of energy, pharmaceuticals, textiles, plastics, metals, and single-use devices. As Indy Johar of Dark Matter Labs argues, *"*our material economy is the main cause of environmental damage globally… 90% of biodiversity loss is caused by resource extraction and processing*"* (Johar 2025). The NHS exemplifies this dilemma. It is simultaneously a site of care and one of the UK's largest material consumers, producing vast volumes of carbon emissions and waste. Scrubs, surgical instruments, and medical plastics circulate through linear supply chains that often end in landfill or incineration, embedding the health service within extractive and unsustainable systems. Addressing the climate emergency therefore cannot be achieved through clinical reform alone; it requires systemic transformation of the material cultures of healthcare.

In Scotland, these challenges intersect with the historical and symbolic importance of the National Health Service (NHS). Founded in 1948, the NHS embodies principles of equity and collective care that remain central to the nation's political and cultural identity. By 2048, NHS Scotland will mark its centenary – a milestone that raises urgent questions:

1. How might a future NHS not only endure but transform, reducing its material footprint while maintaining equitable provision of care?
2. What would it mean for healthcare infrastructures to move from linear to circular models, and from extractive to regenerative practices?
3. How might speculative design help us reimagine NHS Scotland's centenary as a space for radical possibilities of care and sustainability?

These questions provided the starting point for the research outlined in this paper, which set out to explore how speculative design might be mobilized to imagine and prototype a climate-resilient NHS Scotland in 2048, with a particular focus on material flows. The project culminated in *Circulate*, a speculative board game designed to enable participants to interrogate the entanglements of healthcare, material use, and circular innovation.

Healthcare cannot be understood in isolation from the ecological and economic systems that sustain it. Hospitals and clinics depend on global supply chains that are increasingly precarious under climate-induced disruption. NHS Scotland experts have identified textiles and surgical instruments such as scissors as especially impactful areas for innovation, since their widespread single use epitomises the unsustainable linearity of current practice. Confronting these challenges requires healthcare institutions to recognise themselves not only as providers of care but as actors embedded within global material economies.

Within this context, the circular economy offers one pathway forward, emphasizing the minimization of waste and the optimization of material resource flows. Yet regenerative design pushes this further, aiming not only to close loops but to actively enhance ecosystems and community resilience. Watson's (2019) work demonstrates how infrastructures can be designed to restore, rather than simply reduce, ecological impacts by drawing on Indigenous and vernacular systems of stewardship. For the NHS, this implies a decisive shift: from efficiency-driven reforms toward systemic approaches that reduce material throughput, embed circular practices in procurement and operations, and pursue regenerative alternatives that strengthen both ecological health and social equity. The challenge is not simply to do more with less, but to reimagine healthcare infrastructures in ways that are innovative, imaginative, and centred on people and planet.

This project applies speculative design to the specific challenge of material flows in NHS Scotland. It builds on what Candy and Potter (2019) term design-led futures thinking, where design functions as both an imaginative tool for constructing possible futures and as a dialogic medium for engaging publics in their exploration. Unlike conventional futures approaches, which often privilege forecasting, speculative design embraces futures as plural, contingent, and contestable. The aim here is not to predict the NHS in 2048 but to explore how it might evolve if circularity and material stewardship were placed at the heart of its transformation.

The research culminated in *Circulate*, a speculative board game co-designed with V&A Dundee and Studio Andthen. As a "diegetic prototype" (Kirby 2010), the game materializes speculative scenarios around NHS material flows, enabling participants to interrogate the sustainability of products and systems from the supply chain of surgical instruments to the lifecycle of medical textiles. By embedding material considerations into gameplay, *Circulate* created a space for both critique and co-creation, surfacing tacit knowledge and generating new imaginaries for healthcare futures.

By situating healthcare within the broader dynamics of material economies, this paper advances three interrelated contributions. First, it foregrounds material flows as a critical but underexamined dimension of health system resilience in the context of climate transition. Second, it demonstrates how speculative design operationalized through a participatory board game can make complex futures tangible, enabling diverse publics and professionals to interrogate, debate, and co-create alternative pathways. Third, it positions design not only as a means of envisioning possibilities but as a mediating practice that bridges systemic analysis, institutional transformation, and civic engagement. Taken together, these contributions argue for the centrality of design-led, imaginative, and regenerative approaches in preparing NHS Scotland and by extension other healthcare systems for the intertwined challenges of ecological crisis and social equity.

The following section sets out the project's methodological foundations. It outlines how speculative design was operationalized within this research, how iterative workshops informed the development of *Circulate*, and how the game itself functioned as both a research method and a participatory tool for exploring futures of material flow in healthcare.

2. Methods and Approach: Design-led Futures Thinking

This project employed speculative design as its principal method to investigate how NHS Scotland might adapt to the climate emergency by its centenary in 2048. Speculative design, as articulated by Dunne and Raby (2013), extends beyond conventional problem-solving to create artefacts and scenarios that provoke reflection on alternative social, cultural, and technological trajectories. For Malpass (2017), this is a mode of critical practice capable of unsettling assumptions and opening space for debate, while Foster (2025) frames it as "anticipatory prototyping" – a rehearsal of institutional futures under uncertainty in which speculative artefacts act as rehearsals for uncertain institutional futures. Tonkinwise (2014) further positions speculative design as a critical mode that unsettles assumptions and generates new perspectives on systemic challenges. Applied to healthcare, speculative design makes material flows discussable by transforming abstract sustainability imperatives into situated participatory encounters.

Our aim was to use speculative design not only as a means of imagining possible healthcare futures but also as a framework for participatory exploration. As Dunne and Raby (2013) describe, speculative design offers a way of materializing alternative scenarios that provoke reflection and debate, while Auger (2013) highlights how such artefacts make abstract futures tangible and open to interrogation. Building on these perspectives, the project centred on the development of a speculative board game. Games are particularly well suited to participatory futures methods: they structure interaction, invite improvisation, and enable participants to grapple with complexity in a low-risk environment (Coulton et al. 2018).

By embedding speculative design into a game-based format, the project sought to achieve three objectives: (1) situate futures discourse within the material realities of NHS operations; (2) democratise participation by engaging diverse publics in structured yet playful speculation; and (3) generate insights into how healthcare institutions might reconfigure material flows in response to climate pressures. In this way, *Circulate* functions as both method and medium – a speculative artefact that simultaneously embodies and enables the participatory construction of alternative healthcare futures.

2.1. Workshop Development

The speculative board game at the centre of this project was iteratively developed and tested through a series of workshops held between April and June 2025 at V&A Dundee – Scotland's design museum. These sessions engaged a diverse range of participants including designers, NHS staff, researchers, and healthcare practitioners to capture multiple perspectives on the challenges of building a climate-resilient healthcare system through speculative design.

Workshop 1 was facilitated by V&A Dundee's design research team and focused on mapping the lifecycle of everyday NHS products such as surgical scissors and disposable scrubs. Participants included an NHS laundry manager, a consultant surgeon, a NHS Scotland board member, designers, business managers, and senior academics with expertise in climate data, creative intelligence, and medical innovation. Working in small groups, they used the IDEO Circular Design Toolkit (IDEO and Ellen MacArthur Foundation 2016) alongside a bespoke 'circular design canvas' created for the project. Together, they traced material flows from extraction and manufacturing through use, disposal, and potential recovery. These mapping exercises revealed key pain points, including dependence on fragile global supply chains, the limited recyclability of medical textiles, and a cultural attachment to disposability within clinical contexts. Ideation activities then followed, generating speculative interventions to address waste reduction, supply chain resilience, and product longevity.

Image 1: Workshop 1 participants using circular design canvas and discussing medical textile waste. Credit: Dylan Drummond

Workshop 2 built on the insights from Workshop 1 and was designed and facilitated by Studio Andthen, who undertook pre-work to prototype an early analogue version of the speculative game in paper form. Participants tested preliminary mechanics that translated systemic healthcare challenges into playable interactions. The aim of the game was for players to *circulate* - moving around the board to avoid ending up at the centre, which represented landfill. Gameplay was structured around selecting cards, prompts, and challenges that encouraged discussion, while the prototype itself prompted a re-think of the board's design to optimise these opportunities for engagement. Although intentionally low fidelity, the session validated the potential of the speculative format to provoke creative, collaborative responses. Feedback highlighted the importance of balancing accessibility with complexity, ensuring the game could remain engaging for general audiences while also offering sufficient rigour for professional stakeholders.

Image 2: Workshop 2 participants engaging with an early prototype of *Circulate*. Credit: Dylan Drummond

Workshop 3 highlighted the value of speculative design as a way to rehearse alternative futures and surface possibilities beyond conventional planning. Tested in situ at V&A Dundee through drop-in sessions with a range of experts, the refined prototype demonstrated the game's dual potential: as a tangible training tool for NHS Scotland staff, aligned with professional development, and as a public engagement resource for the museum to spark wider conversations about the circular economy and sustainability. By situating participants in a facilitated gameplay environment, the workshop created a safe but provocative space to question assumptions while engaging with plausible climate futures. Teams collaboratively prototyped resilient healthcare strategies in response to simulated shocks such as extreme weather events or disrupted supply chains. In doing so, the game showed how speculative design can function simultaneously as an educational tool and a research method, surfacing tacit knowledge and institutional assumptions while fostering novel ideas.

Image 3: Refined prototype testing taking place at V&A Dundee design museum. Credit: Grant Anderson

Across these three workshops, *Circulate* evolved from a conceptual experiment in circular design to a robust speculative tool for participatory futures-making in healthcare. The iterative, cross-sector process ensured that the final prototype was grounded in practical expertise, responsive to systemic challenges, and accessible to a wide public audience. Importantly, the workshops highlighted opportunities to embed circular economy principles and reduce carbon footprints across procurement, use, and disposal. The project drew on sustainable product design literature (Bakker et al. 2014) and transition design frameworks (Irwin 2015; Manzini 2015), framing the NHS not solely as a provider of clinical services but as a dynamic socio-technical system that must adapt across ecological, operational, and cultural dimensions. These insights directly informed the game mechanics and narrative content.

3. Designing the Game and Outcomes

The speculative futures game has been developed in both analogue and digital formats, functioning as a participatory tool for foresight, systems thinking, and imaginative scenario planning. The online version can be accessed here[1].

Image 4: Refined prototype testing taking place in the museum. Credit: Grant Anderson

Drawing on design fiction methodologies (Dunne & Raby 2013; Coulton et al. 2018), the game invited participants to engage with future-oriented narratives, asking how NHS infrastructures, technologies, behaviours, and practices of material flow might evolve under a circular economy model. Rather than forecasting, the intent was to provoke reflection stimulating debate on how systemic change in procurement, reuse, repair, and waste reduction could reshape the circulation of materials within NHS settings. Scenarios explored included the reuse of PPE through sterilization technologies, the remanufacturing of medical devices, and the redesign of supply chains to enable closed-loop circulation of consumables. By situating such possibilities under conditions of environmental duress, participants were encouraged to consider how circular practices could become embedded within the NHS, not as optional add-ons but as integral to future resilience.

Studio Andthen translated research insights from the workshops into a modular experience toolkit that combined narrative and co-design components. The game mechanics included:

- Global Event cards presenting climate-altered futures such as severe weather disruptions, decarbonization mandates, or supply chain collapse.
- Circular innovation cards prompting players to imagine new products, services, and systems for healthcare.
- Phase cards structured around lifecycle stages of make, use, maintain, recover to foreground circular processes and interdependencies.
- Idea mapping worksheets to capture speculative interventions and balance environmental, clinical, and user considerations.

During gameplay, participants developed interventions ranging from decentralized solar-powered care hubs to regenerative material systems for medical garments and AI-supported triage for climate-induced health conditions. These concepts were intentionally framed as 'futurescapes' (Auger 2013; DiSalvo 2009): provocations designed to surface tensions and trade-offs between feasibility, desirability, and sustainability.

Sustainability was embedded not only in the thematic focus of the game but also in its material production. Printed components were produced locally using recyclable materials, while digital resources were optimised for low-carbon distribution. Accessibility and usability were prioritised to ensure the toolkit could be adapted to varied contexts and audiences without loss of impact.

The final deliverables included:

- A fully developed analogue board game and facilitation toolkit for professional and educational workshops.
- A downloadable open-source PDF version, enabling broader access and integration into climate-health initiatives.
- A short film documenting the design process, showcasing the collaborative ethos of the project and demonstrating speculative design's civic value.

The game was intentionally designed for multiple audiences. For members of the public, it emphazised imagination, accessibility, and storytelling, making the abstract notion of climate resilience tangible and engaging. For NHS staff, it served as an entry point into systems thinking, prompting reflection on how everyday roles and routines might shift under ecological pressures. For engineers and manufacturers, it created a speculative platform to reconsider established production processes and infrastructures.

1 https://designhopes.org/project/circulate-reimagining-a-climate-resilient-nhs-scotland/

In this sense, the game operated as a 'boundary object' (Star & Griesemer 1989): an artefact that enabled collaboration across diverse perspectives without requiring consensus. By positioning speculation as both playful and critical, *Circulate* bridged public engagement, professional expertise, and systemic inquiry, generating more resilient imaginaries for healthcare futures.

4. Embedding Circulate within the NHS and Future Potential

While the workshops and public engagement activities demonstrated the value of *Circulate* as a speculative tool, its longer-term potential lies in embedding it within NHS contexts. The project has identified three areas where the game could contribute to institutional transformation. First, the NHS is actively exploring how to build climate resilience into its workforce strategy. *Circulate* provides a structured format for staff to collectively explore climate scenarios, rehearse adaptive strategies, and reflect on how material choices shape clinical practice. As Johar (2025) notes, material economies underpin environmental breakdown; by engaging with this reality through gameplay, NHS staff can connect systemic sustainability challenges to their professional responsibilities.

Second, as one of the UK's largest buyers of goods and services, NHS procurement exerts significant environmental impact. Here the game can act as a foresight tool, enabling procurement teams to anticipate risks in supply chains, test circular alternatives, and interrogate assumptions embedded in current processes. This aligns with the Design Council's Design for Planet mission (2021) and the NHS's ongoing commitments to carbon reduction.

Third, the game has value as an educational resource beyond the NHS. In design and healthcare curricula, it introduces students to systemic thinking and speculative methods; within museum contexts such as the planned V&A Dundee exhibition, it functions as a civic platform for public deliberation on healthcare, climate, and material flows. This reflects Julier's (2017) notion of design culture as an expanded field mediating societal challenges.

Future development will focus on scaling *Circulate* as an open-source toolkit, adaptable for different regional contexts and healthcare systems. With international collaboration, it could address shared material challenges across healthcare systems worldwide. By embedding circular principles and speculative methods into everyday practice, *Circulate* demonstrates how design can contribute not only to imagining but also to enacting more sustainable futures.

5. Conclusion and Next Steps

This project aligns with global research agendas on climate resilience and the green transition, showing how design-led innovation can drive strategic transformation within public institutions. Building on scholarship on design's role in institutional change (Bason et al. 2014; Julier 2017), it demonstrates that speculative design can enable systemic shifts by reconfiguring relationships between people, materials, and future imaginaries.

The museum context proved an effective civic platform, advancing two interrelated aims: deepening public understanding of design's societal role and contributing to Scotland's Green Transition. Here, the workshops positioned the speculative game as both a pedagogical device and a participatory platform, bridging academic research, professional expertise, and public engagement.

Looking ahead, the game is being developed as a professional development tool for NHS Scotland, offering staff structured opportunities to anticipate climate adaptation challenges and reflect on the material implications of practice. It is also envisioned as an educational resource within design curricula, helping students engage critically with systemic transformation and the role of design in shaping public institutions.

In addressing the research questions, the project showed: first, how a future NHS might not only endure but transform, reducing its material footprint while sustaining equitable care through circular and regenerative strategies; second, what it would mean for healthcare infrastructures to move from linear to circular models, embedding reuse, repair, and closed-loop flows; and third, how speculative design can reframe NHS Scotland's centenary as an opportunity to explore radical possibilities of care and sustainability.

In conclusion, the project illustrates the capacity of speculative design to catalyze dialogue, collaboration, and critical reflection within complex public systems. By envisioning how NHS Scotland might operate under radically altered environmental conditions, it created participatory spaces for bold speculation grounded in material realities. More broadly, as healthcare systems worldwide confront the challenges of climate adaptation, this work offers a replicable model for engaging diverse publics in co-designing sustainable futures. It underscores the distinctive contributions of design not only to imagining alternative trajectories but also to shaping the infrastructures of care in the present.

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THEME 3

Policy and Design — Shaping a Global Response

Policy frameworks are critical in driving large-scale design innovation and environmental action. This theme addresses how design can influence, and be influenced by, global policy efforts such as climate adaptation strategies, urban resilience planning and international agreements like the 2015 Paris Accord.

All Tomorrow's Policies: A Design Framework for 'Next Administration' Social Innovation

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Abstract

This paper addresses the present-innovation bias in civic design, where government innovation teams disproportionately focus on short-term solutions, driven by political cycles and resource pressures. The author argues this approach is insufficient for tackling systemic social challenges. Drawing on over a decade of collaborations by the Public Policy Lab with US federal, state, and local government, the paper proposes an adaptable, dual-timeframe framework. This model leverages participatory, human-centred design to meet immediate political needs while simultaneously advancing large-scale innovations. The framework's key concept is the 'next administration timeframe' (4-12 years), identified as the critical, politically realistic window for deploying transformative systems. By operating on both current and future timeframes, designers can use today's urgency to lay the foundation for more sustainable and just futures. The model, supported by reference to applied work, is relevant to any complex organization managing short-term pressures against long-term goals.

Keywords: Futures, governance, implementation, policy design, public-sector innovation.

Introduction

This paper proposes an adaptable framework for design-led innovation in policy contexts that is both responsive to short-term political pressures and also intended to lay foundations for large-scale system improvement in a future timeframe. Drawing on experience from nearly 15 years of collaborations between design teams at the Public Policy Lab, a not-for-profit design innovation lab based in New York City (USA), and policymakers in national, state, and local governments in the United States of America, this paper names the drivers of present-innovation bias that are particular to policy contexts; identifies participatory design methods that can usefully deepen the time-horizon of civic design; and cites current experiments in civic design aimed at fostering 'next administration' government innovation for more sustainable and just futures. The proposed methodology provides a necessary augmentation to traditional policy planning, which often fails to address even medium-term time horizons, in part because of the ambiguity inherent in proposing system-level change for unpredictable future contexts. In environments where leaders face decisions beyond mere statistical prediction, a framework that incorporates human-centred design and futures approaches is essential for managing what has been termed 'radical uncertainty' (Kay and King 2020).

While the paper focuses specifically on policy and social-service design conducted within public systems, the framework for future innovation deployment that the paper proposes will be germane to designers and strategists working in any complex organizational environment – in the public or private sector – where leaders are more beholden to quarterly earnings or election cycles than to sustained community or environmental gains.

The Timeframe for Transformative Policy Design

Human-centred design methods have increasingly been adopted by policymakers and by innovation teams working in or for government (van Buren et al. 2023; Wellstead 2021). However, civic designers have most typically focused on developing solutions – whether products, services, or policies – to redress pressing 'current-state' problems in policy and service delivery. Further, the administrative preference for stable, rational, technological solutions tends to constrain human-centred undertakings (which tolerate changeable, intuitive, and embodied experience) to incremental improvements, what some have termed "microinnovations" (Kelman 2021), often resulting in renovations of existing service flaws rather than fundamental reconstruction of the system's core features.

This present bias, which exists in most realms of human endeavour, is particularly reinforced in policy organizations, which often operate within a temporal context that cripples attempts at systemic change; while the goal of transformative policy necessitates structural overhaul, the institutional reality favours short-cycle political incentives and rapid, visible results (Molica 2025; Ogami 2024). This author has observed in practice that two- to five-year political terms, genuine commitment to alleviating immediate social suffering, and/or resource scarcity (real or generated) work together to create pressure for civic innovators to focus on six- to 18-month timeframes. That short time horizon is insufficient for the whole-of-system innovations required to build more generative social futures – and it is particularly inappropriate to address complex and non-linear challenges such as ongoing climate change, aging populations, and income inequality.

The author proposes that the appropriate scale for transformative design in government service innovation is, firstly, not the 20-, 30-, or 50-year 'future generations' timeframes beloved of futures thinkers. In the United States of America, that timeframe (while perhaps appropriate to the scale of global challenges) has proved politically unsatisfying for most elected officials and insufficiently aligned with the implementation mandate of agency leadership, as Molica and Ogami describe. Nor, in the author's experience, is the appropriate timeframe the two- to five-year periods that are the purview of agency strategic leadership – and of a typical design team working in policy contexts. That timescale provides insufficient runway for meaningful social innovation to achieve lift-off.

Rather, civic designers must focus on the neglected middle child of the 'next administration's future' – a future that arrives from at least five and perhaps as much as 12 years into the future, when a current administration in a Western democracy can expect to be out of power. This 'next administration' timeframe is the necessary space for designing and deploying new systems for social value – designed policy solutions that are considerably more ambitious than typical 'renovations' of existing policy-delivery systems, but not so radical as to generate resistance to calls for a new social order.

Image 1: Innovation teams at the Public Policy lab use a five-phase model to generate near-term and next term interventions in policy systems. Credit: Public Policy Lab

A Design Framework for the Next Administration

How can the civic designer, employed by or in collaboration with any particular administration, convince current leadership to support systemic social innovation? Especially when the cost will be borne now, but the benefit will arrive in a future administration – perhaps even one led by political rivals? Said another way, how does a futures-minded designer leverage the regulatory and intuitional goals of today to deploy design solutions that build toward more regenerative futures?

Existing design frameworks for human-centred research and design – which privilege participatory and embodied intelligences over mediated and digital ones – can and must be converted into dual-timeframe models that leverage current-state urgency for the future's benefit. This two-timeframe approach delivers what political systems need right now, while also testing and preparing for more transformative social change to come. Crucially, sustaining this long-term work requires agile and collaborative leadership across the organization, transforming the organizational culture toward public entrepreneurship where staff are empowered to rally resources and work across sector lines (Naatujuna 2022). Designers working in policy contexts can leverage current innovation efforts to simultaneously build constituencies and evidence – and even preliminary foundation-building – for transformative work keyed to longer timeframes.

This dual-timeframe approach can be grounded in an innovation organization's current practice. At the Public Policy Lab, human-centred researchers and designers have collaborated on significant policy- and service-design projects with the White House, federal executive agencies, state-level departments and courts, and multiple agencies of the City of New York, along with other municipal partners. Project products include new service interfaces (communications, forms, digital apps, etc.), new models for service interaction and delivery, new strategic frameworks for policy operations and governance, and concepts for policy innovation; subject areas include policy and services for low-income families and children, older adults, veterans, people dealing with homelessness and health challenges, people who've been previously incarcerated, and other members of the public who are less likely to have institutional power. In those engagements, Public Policy Lab teams use a five-phase, ten-step model to conduct projects, known as PPL's Standard Release Model. This model, a human-centred adaptation of the sprint-and-release approach pioneered by Agile software developers, allows innovation partnerships to successfully deliver a project, on time and on budget, while allowing for ongoing iteration and adaptation during project development. Sprints are two-week time periods that result in incremental completed activities or products that build toward a release. A release is a set of one or more sprints that results in the delivery of a complete innovation product. Based on project goals, timeline, and available budget, the Public Policy Lab develops a scope-of-work that includes all or a subset of these releases.

A full-cycle innovation project led by the Public Policy Lab produces ten innovation products, one associated with each standard release, each couplet of which constitutes a phase, as shown in the Table 1 below:

Public Policy Lab Standard Release Model			
PHASES	**STANDARD RELEASES**	**STANDARD DELIVERABLE**	**RELEASE GOAL**
Plan	R1: Scope	Project Plan	Clarify project stakeholders, inquiry areas, and desired outcomes.
	R2: Define	Research Plan	Develop research tools and identify/schedule specific research participants and resources.
Research	R3: Discover	Discovery Findings	Document policy and service context, and collect and share participants' experiences and voices with decision-makers.
	R4: Synthesize	Preliminary Concepts	Identify top opportunities from research for improved policy and service delivery.
Design	R5: Co-Design	Launch-Ready Prototypes	Co-create viable prototypes of new policies, services, and products with end-users and providers.
	R6: Prepare	Launch Plan	Create necessary systems and buy-in for initial live launch of minimum viable prototypes (MVPs).
Deploy	R7: Test	Evaluation Results	Capture end-user and provider experiences during initial live implementation.
	R8: Redesign	Scaling Plan & Revised Products	Redesign products based on learnings from initial implementation.
Scale	R9: Integrate	Approved Final Products	Obtain translations, system integrations, and sign-offs required for scaled implementation.
	R10: Share	Project Storytelling	Support operations teams in systemwide roll-out and create project documentation.

Table 1: A full-cycle innovation project led by the Public Policy Lab produces ten innovation products.

In addition to providing a roadmap for current-state innovation efforts, this framework can be used to guide development of design interventions that operate simultaneously on a current- and a future-administration timeframe, allowing current-state policy delivery to plant the seeds of future transformations that need more than one election cycle to grow to scale. Each of the standard deliverables described above can incorporate components that speak to current-state needs (by definition, about what is necessary now, not in the future) and also to more significant systemic interventions or reinventions – the future state of policy and service delivery that is unhooked from immediate system requirements and yet still foreseeable enough as to allow for operational preparation.

Note that it's crucial that the deliverables reside in both timeframes simultaneously: if the civic innovation team shifts to addressing only the 'next administration' outcome, it will fail to grapple seriously enough with the demands of right now – which is where resources and political will still reside. The dual-timeframe model this author proposes allows for satisfaction of now-state requirements while also leveraging current momentum for a longer-term and more substantive transformation.

Dual-timeframe Deliverables

Specific components, methods, or outputs in each phase and release can speak to each of the two different time horizons under consideration by any given project team. At every step, typical 'now-state' deliverables can be converted into dual-timeframe outputs, as described below, with reference to particular suggested methods.

Plan

The intent of the Plan phase is to illuminate the operational and political realities that drive and constrain a government group that is sponsoring an innovation effort, while also defining the change motivations and activities that animate the participating innovation practitioners. To that end, the output of Release 1 is a project plan that results from collaborative activities intended to define 'known unknowns' (areas of inquiry that will drive discovery research), human participants and stakeholders in the project domain, and potential project results that would represent a successful project outcome; the output of Release 2 is a research plan, which usually includes a theory of whom the team will engage in discovery activities, what prompts and activities will be used to collect information, and what tools and approaches (from consent materials to payment mechanisms) will ensure ethical collaboration. Innovation teams may also use this phase to engage expert respondents, explore prior related work (and why it succeeded or failed), and to seek a preliminary understanding of who in the targeted policy-delivery system holds authorizing power that will be required for ultimate implementation of any innovation products.

To convert the activities of this phase to a dual-timeframe model, teams must begin by clearly defining, with project stakeholders – typically senior leadership with policy and/or operations responsibilities – what constitutes 'now' or 'soon' versus what constitutes 'later'. They then can use those definitions to identify what further understanding needs to be developed about each of those timeframes and who holds the requisite knowledge to help build that understanding. So, in addition to doing typical 'now-state' stakeholder mapping, teams might also map the separate set of potential future stakeholders and identify what representatives of those populations are best able to contemplate potential future needs and aspirations. In preparation for discovery engagement, teams can develop discussion guides and other research stimuli specifically intended to elicit and explore future needs and aspirations in addition to current and past experiences.

We believe this phase is also a crucial moment to introduce project participants who may not be familiar with futures approaches to the conceptual frame of multiple potential futures and key mental models for futures exploration like, for example, Sharpe et al.'s (2016) three-horizons framework, which describes how the status quo present can mutate into desired futures and highlights how divergent outcomes may emerge from the necessary conflict between the established system and new visions. It's vital that the innovation team prepare partners and stakeholders for upcoming deliverables that will speak simultaneously to two timeframes and get buy-in for that approach.

Research

In the Research phase, the innovation team's task is, first, to capture policy and service context and to collect and share participants' experiences and voices with decision-makers, then use those findings

to do meaning-making and opportunity identification for improved policy and service delivery. The result of that synthesis process is a set of initial design concepts that can be used to set direction for iterative collaborative design activities to follow.

Teams at the Public Policy Lab have recurrently dealt with the 'problem' of emergent futures during this phase of work, as discovery efforts that are intended to illuminate recent conditions and in-scope, current-term opportunities for delivery improvement additionally reveal more profound social failures that demand comprehensive policy and systems remedies. When a policy innovation effort is scoped as a single-timeframe effort, intended to only deliver current-term interventions, these future-oriented findings are genuinely problematic: design concepts that speak to next-administration timeframes may be perceived as superfluous at best or, at worst, a misread of project goals that undermines trust between the innovation team and policy or operations partners. Meanwhile, design researchers may feel ethically compromised if they do not develop design concepts that respond to participants' expressed needs for systemic transformation. In the context of contractually defined innovation work, these out-of-timeframe outputs end up often bucketed under a 'for future consideration' or 'recommendations' framing – effectively siloing them from serious consideration or implementation.

In a dual-timeframe model, in contrast, findings that speak to future needs and aspirations are deliberately elicited and presented as valuable inspiration for next-administration foresight. Researchers can use methods of anticipatory anthropology, such as the Ethnographic Futures Research (EFR) technique codified by Robert Textor, to mitigate 'tempocentrism' by digging into participants' hopeful, pessimistic, and pragmatic future views (English-Lueck and Avery, 2020). Beyond observing current-state pain, deep inquiry methods such as Causal Layered Analysis (CLA) can be integrated to systematically deconstruct policy issues and expose the underlying metaphors and worldviews that support the current system's present bias (Inayatullah 1998).

Design concepts that suggest opportunities to prototype for the future are developed as companion pieces for current-term concepts – usefully removing the pressure from immediate interventions to overreach and attempt to solve for significant issues that are, in fact, outside the capacity of their time purview to resolve. When presented with intentionality and polish, next-administration futures findings and concepts can support renewed purpose and ambition.

Any of the typical now-state methods and outputs of service-design research and synthesis can also be bent toward the future – for example, research findings can highlight quotes from participants that speak to future events or expectations, and journey maps and service blueprints can be used to represent future conditions. More evocative futures outputs, such as those that map and visualize potential futures, are described by Candy and Kornet (2019) in their discussion of the Ethnographic Experiential Futures (EXF) Cycle. These speculative visions can be understood as the representation of potential collective policy and service models, not just as personal/individual fantasies ('fantasy' being the future-shifted analogue to 'anecdote' in the present tense).

Design

During the Design phase, an innovation team using a dual-timeframe model makes a crucial turn: whereas earlier phases treated the next-administration time horizon as a space for imagination, in co-design and preparation for launch, imagination must be developed into deployable prototypes for testing. This development process happens alongside creation of current-state prototypes, requiring clarity and attention from the design team to keep prototypes, as they move through rounds of iteration, firmly situated in the needs and embodied experience of their intended timeframe, whether that be the near term or the longer horizon of the next administration.

When creating now-state prototypes, Public Policy Lab teams conduct participatory design activities with members of the public and systems operators, usually through multiple rounds of iterative development. Designers also often find it helpful to conduct deep dives or system immersions into the specifics of regulation or operations during this phase, in order to understand how to appropriately tailor prototypes for real-world testing inside of existing constraints. The introduction of tools enabled by Generative AI is creating new opportunities to quickly translate complex legislative requirements into computable rules, logic models, plain-language summaries (Kennan et al. 2025); the Public Policy Lab is developing GenAI tools to rapidly generate visual prototypes of benefits notices for iteration, for example. Some researchers are also exploring the use of 'governance in silico' models that use GenAI to simulate demographic and behavioural data that represent the behaviours of diverse stakeholders (e.g., residents, case managers, policy leaders, etc.), then use the simulations as a so-called sandbox to test the impact of new services or policies before real-world deployment (Wang 2025). It's likely that these methods will be increasingly useful in rapidly creating both now-state and future state prototypes, in collaboration with human users and designers.

In contrast to AI tools, other approaches specifically leverage embodied human perception to generate potential policy and service futures: Designers may be able to shift co-design activities into next administration timeframes through the use of experiential future scenarios, "embodied and emotional experiences [that] enhance participants' engagement with futures" (Hoffman 2024, 4). While now-state prototypes benefit from being surrounded, contextually, with the actual sensations and feelings of the current moment, future-state prototype development can be enhanced by providing emotional and somatic cues to help situate the in-development tools, materials, or services in potential future realities. For even greater verisimilitude, the design team can look for what's been memorably described as "pockets of the future" that exist "embedded in the present" (Curry and Hodgson 2008, 3) – people and situations who already represent a probable future development. To draw from the Public Policy Lab's work on the policy and service requirements of older adults, a small precentage of current septuagenarians are frequent and savvy users of digital technologies; the digital-accessibility challenges they experience – driven by cultural, cognitive, and physical aspects of aging – may presage future challenges that Gen Xers and Millennials will have as they age, facing an even more digitized service environment. Future-timeframe prototypes can be developed in collaboration with those online 70-somethings serving as stand-ins for their now-midlife children.

In preparation for testing, innovation teams will need to determine what populations and locales can best serve as pilot environments for their now-state and future-state prototypes – and what supports and training operational staff require to implement pilot testing. (Note that, in public-sector contexts, the innovation team is often not the delivery team; rather, innovators must work with operations teams to transfer understanding of prototype interventions in advance of piloting.) Given the typical time and funding constraints of most policy-innovation projects, the author suggests that the 'pockets of the future' approach, when available, may be the preferred option.

Deploy

It is essential to recognize that even highly successful innovations face significant scaling challenges. As Megan Stevenson notes in her magisterial review of the efficacy of randomized controlled trials, "You can't pilot test large-scale or systemic reform. We don't have good tools to map the causal structure of the social world when it comes to social or technological revolutions. Predictions depend more on theory, ideology, analogy, and assumption" (Stevenson 2023, 2042). Yet, in the fourth phase, Deploy, civic innovation teams attempt to monitor and evaluate the real-world, small-scale implementations of the prototypes they've co-limited with policy users and providers. They document end-user and provider experiences, make assessments about how to address prototype failures and augment successes, and then redesign their interventions based on those learnings. Finally, they work with policy and operations partners to develop a plan for scaling the innovation products across what this author has described elsewhere as the "policy-delivery stack" (Edmundson et al. 2025, 52)

– the multiple functions of government, from front-end service delivery to operations and strategic systems and processes, to underlying policy authorization, that constitute what the Public Policy Lab also calls the public policy 'layer cake' (Public Policy Lab 2025).

For innovation teams working on a dual-timeframe model, the process for monitoring and evaluating near-term and next-term interventions is similar – qualitative and quantitative assessments of both implementation feasibility and experienced alterations in behaviour and outcome for prototype users. The assessment challenge for next-term prototypes, however, is that while it may be possible to document usability and impact of the prototypes in the 'pockets of the future' selected for piloting, those emergent examples of future conditions are singular and specific – while potential futures, even on a five to 12-year timeframe, are plural. Teams may therefore also want to engage in theory-driven evaluation (TDE) by attempting speculative assessments to capture potential usability challenges in multiple iterations of the future, using scenarios to stress-test prototypes in different versions of next-term reality (Derbyshire 2018).

The most significant challenge to a dual-timeframe model comes in the final sprints of Deploy, when the innovation team collaborates with policy and operations partners to develop a scaling plan. For the near-term prototypes, implementation is optimized for current-state needs and resources. The next-term prototypes, on the other hand, must be launched now (or soon) but are not expected to generate payoff for years to come – even while they demand resources and will immediately. Teams may be tempted to take a slow-adoption approach, where resource requirements ramp up over time, as the next-term intervention comes closer to fruition. However, this incremental approach often undercuts the success of systemic change before it has the chance to take hold, by starving the implementation of capital and commitment. Rather, the hope is that the deliberate efforts of the prior releases, to build understanding and intention around future solutions, pays off here with buy-in from decision makers to invest in the current moment in longer-term system change efforts.

Scale

By the final phase, Scale, responsibility for implementation shifts fully to policy and operations teams that manage the policy-delivery stack. Innovation teams can provide support, but institutional decision-makers must ultimately authorize translations, system integrations, and sign-offs required for scaled implementation. In a dual-timeframe model, they must do this for both near-term interventions and also for next-term innovations, as described above. Where innovation teams can be of most help is in supporting policy and operations teams in systemwide roll-out and project storytelling – the activities that will drive understanding and adoption across a policy system.

Overcoming Resistance to Dual-timeframe Adoption

It's entirely likely, when proposing a dual-timeframe approach as described above, that advocates for the approach will encounter resistance – both from government policy or operations partners and even among their own innovation colleagues. Advocates can make both tactical and ethical arguments to address hesitation.

Members of innovation teams may argue that developing meaningful and satisfying policy and service interventions is already a fraught process, even when focusing on near-term deployment, with typically not enough time nor resources to also commit to doing 'double the work' to conceive of next-administration interventions. Advocates can address this concern by pointing out that issues of the future are constantly emergent in design-driven policy innovation, but that future-state needs and opportunities have nowhere to reside in projects with only a near-term implementation runway; creating scoping and delivery expectations dedicated to two different timeframes can actually make the innovation process easier, by allowing teams to name and address future concerns independently from near-term issues. Further, adopting a second viable timeframe allows civic innovation teams to work to their fundamental mission, which is supporting the ability of the public to build better lives over time, not only enjoy improved service interfaces right now.

Policy and operations partners may raise an additional concern: that they operate within political systems with time-based authorization that extend only to the next election, or even just to the next budget cycle. Advocates can propose to these partners that considering next-term needs and opportunities is a prudent and laudable form of risk mitigation, attention that's urgently needed to prevent devastating future failures that will have not only profound social effects, but also significant material costs. Further, this dual-timeframe approach serves as an explicit mechanism to address the ethics of temporal governance, enabling current leaders to begin to address the needs of future humans – a mandate recognized in international governance (United Nations General Assembly 2024). The sandwiching of dual-time timeframe approaches will allow the agency to meet the needs of the moment while simultaneously building a better tomorrow – the fundamental role of any democratic governance.

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Allegheny to Chesapeake: Building Maryland's Climate Resilience by Design

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Abstract

This paper builds on efforts to establish MarylandByDesign, a design policy platform advancing climate-focused design in Maryland. Drawing from classical and Eastern elements – earth, water, fire, air, metal, and wood – and a fifth element of life-sustaining energy, it explores how interconnected ecological principles can guide design policy in the age of climate change. Maryland's natural and human resources, from the Chesapeake Bay and Allegheny Mountains to its diverse communities and institutions, provide the foundation for climate-based design innovation. The paper traces Maryland's environmental history, identifies key research centres such as the Smithsonian Environmental Research Center, and highlights policy alignment with the Maryland Commission on Climate Change. Influenced by figures like Rachel Carson and Jane Jacobs and informed by Indigenous knowledge systems, Maryland's designers and educators are developing sustainable design practices that integrate environmental awareness, cultural preservation, and design-led innovation for a resilient future.

Keywords: Climate change, design policy, environmental design, MarylandByDesign, sustainability.

Introduction

The inspiration for this paper is based on previous efforts to establish a design policy platform for the State of Maryland inclusive of design in all forms including related specializations of graphic, industrial, architecture, interior architecture, services, and fashion. Respect for the classical elements in Western philosophy: water, air, earth, and fire, and in Eastern philosophy: wood, fire, earth, metal, and water are fundamental to design in the age of climate change. The fifth element to be included is life sustaining energy or understanding the interconnectedness of all things. These principles frame this narrative about how design in Maryland can address climate change.

Image 1: Calvert Cliffs on the west side of the Chesapeake Bay contain approximately 10-20 million year old sediment and fossils from a coastal ocean covering the area. Credit: Stephanie F. Yoffee

The current cornerstone of design policy in Maryland is to address climate change, and stems from the important natural and human resources within the state. The Allegheny Mountains in Western Maryland and the Chesapeake Bay in Eastern Maryland offer research opportunities and natural resource evidence related to climate change. The human resources including multicultural communities, Native Peoples, and both government/non-government professionals all contribute critical design and scientific knowledge necessary to develop Maryland's design policy. This paper defines the foundation for climate change focused design policies by tracing the history of environmentalism in Maryland, identifying current ongoing climate research resources located in Maryland, providing a summary of Maryland Climate Change Commission's current goals, and outlining design methods and design-led innovation based on climate informed design policies. Case studies of design methods in practice and design education in Maryland, as well as in other states, including Rhode Island School of Design's Nature-Culture-Sustainability Studies concentration (RISD-NCSS 2025) are in a position to develop the ground plan: *Design for Climate in Maryland*.

Image 2: Blue crabs are a native species and the most valuable fishery in the Chesapeake Bay. Credit: Stephanie F. Yoffee

The alignment of Maryland's design policies with the goals set by Maryland Commission on Climate Change (MDE 2023) can be the next chapter in Maryland's Design Policy. The environmental and ecological principles rooted in the State's natural and human resources must be central to design policy to protect and preserve the planet for future generations. The environmental research based in the scientific studies and knowledge about the Chesapeake Bay (UMCES 2025), one of the most important estuaries in North America, combined with innovative design practices in Maryland that are aligned with the current goals of the Maryland Commission on Climate Change (MDE 2025) can inform design policies in Maryland, and around the world.

The Smithsonian Environmental Research Center based in Edgewater, Maryland can be a catalyst for climate-based design research. There are well established Maryland-based programmes which involve design practitioners, individuals and communities in efforts to address climate change. These programmes include The Maryland Historical Trust (Maryland Department of Planning 2025) emphasizing historical and cultural preservation, and The Chesapeake Bay Trust emphasizing watershed conservation (Chesapeake Bay Trust 2025).

It is equally important for individual design practitioners and makers in Maryland to continually adapt their design processes and methods while considering climate change impacts as it relates to sustainable design outcomes including manufactured products, sustainable urban development and the built environment. Maryland has a long history of thought leaders who prioritized the importance of the environment and the natural world. The Native Peoples living in the region prior to 1600 had a highly developed knowledge about the flora and fauna on land and in the water, which views place itself as the teacher, and our human role in relationship with the land as learners and caretakers (University of Maryland 2025). While some of this knowledge has been passed down to the current generation of Native Peoples in the region, much of it has been lost, and replaced with modern environmental education which tends to teach about place in terms of data and presumed scientific objectivity. The importance of continuing to understand our natural environment from an Indigenous perspective is critical for the knowledge and respect of natural resources. This indigenous perspective has been reinforced through recognition by the Governor of Maryland in 2012 when the Native Peoples of the Piscataway-Conony Tribe and the Piscataway Indian Nation were the first tribes officially recognized by Maryland (State of Maryland 2019).

Ecologist Rachel Carson, a celebrated thought leader from Maryland was instrumental in the American environmental movement leading to the global awareness of the harm caused by prolonged pesticide use, and the establishment of Earth Day (Lear 1998). Jane Jacobs, urbanist and writer who worked briefly in the Washington, DC area in the 1950s influenced American city planning and the New Urbanist movement through her writing (Jacobs 2011). Jacobs inspired the first 'Jane's Walk' in Baltimore, Maryland in 2016 motivating people around the world to take walking tours to look at cities and neighborhoods as Jacobs did while writing her books about urban spaces (Gunts 2016). These design methods continue to be used, and have led to innovations in urban design and planning. Carson's and Jacob's perspectives provide the motivation and inspiration to further develop Maryland's sustainable design outcomes.

Design for Climate Change in Maryland: Collaborative Efforts

Formal collaboration with design industries and practitioners in Maryland is foundational for innovations necessary to continue to be at the forefront of implementing climate change policies, and to achieve scalable outcomes. In the past, *MarylandByDesign* has previously taken a leadership role to promote design-led innovation, and address seemingly intractable public sector problems. Advocacy for these open-ended dialogues to reinforce the definition of design in Maryland can continue with the necessary legislative strategy inclusive of a dedicated design commission.

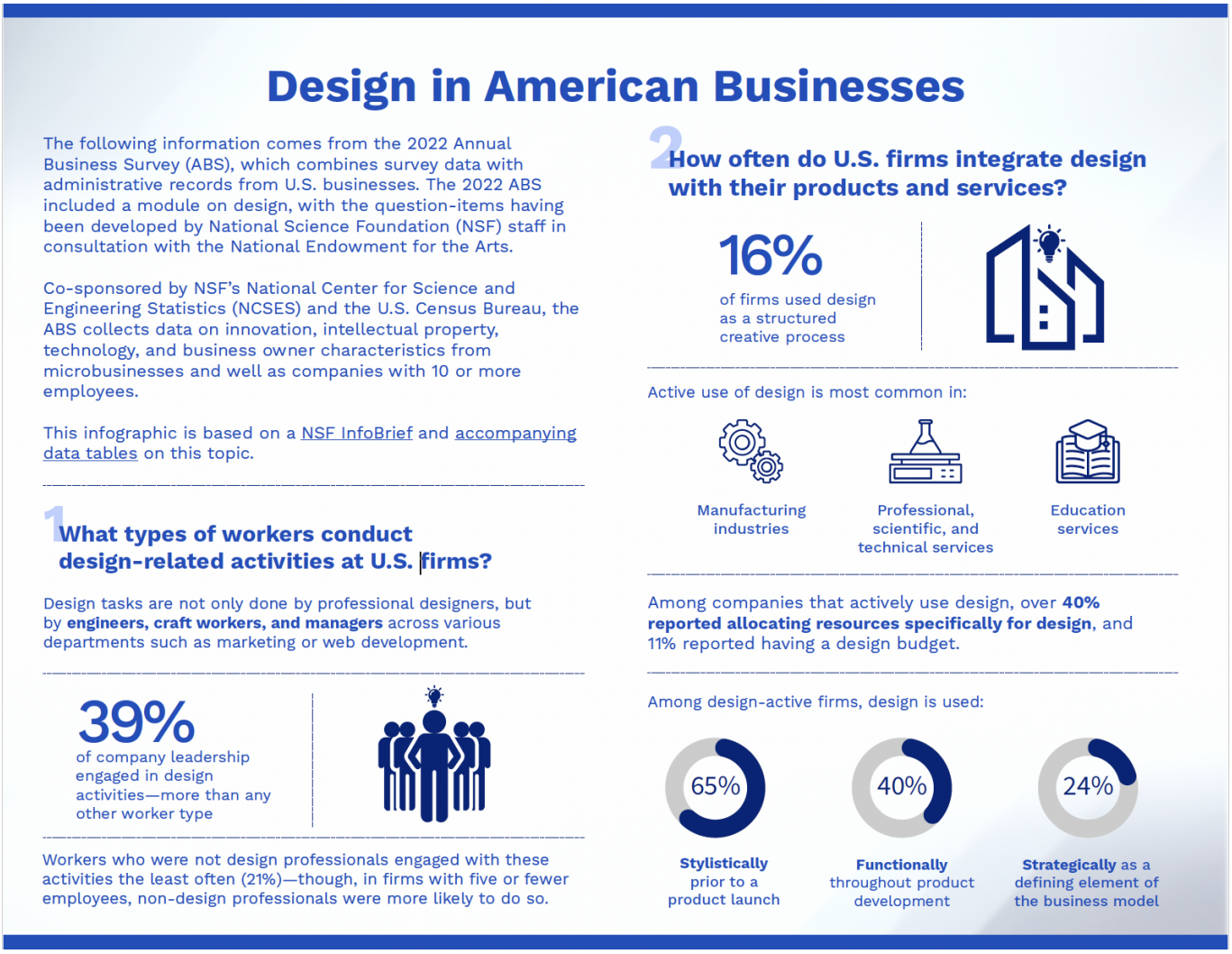

Figure 1: An overview of the data presented as part of the 2022 Annual Design Business Survey. Credit: National Endowment for the Arts

Since more robust surveys of design applications within the public sector are continuing to be developed in the US it is informative to rely on recent survey data for the private sector when understanding the implications of using design methods within an organization. According to the 2022 Annual Design Business Survey, 16% of US firms actively use design, with 40% of these firms allocating resources specifically for design, and 11% having a budget for design (National Endowment for the Arts (NEA) 2022). In 2022, the National Arts Statistics and Evidence-based Reporting Center estimated 997 000 individuals were contributing to US firms in various design occupations regardless of industry, and 39% of company leadership participated in design activities in firms considering design tasks were done by design practitioners, engineers, craft workers and managers (NEA 2022). The relatively small number of individual design practitioners contributing to the large number of US firms as a whole demonstrates the tremendous influence design practitioners already have on outcomes related to achieving climate change goals.

According to the Observatory of Public Sector Innovation, State of Practice, design methodologies are valuable for public sector innovations. Established in 2021, *America is All In* is the largest network of American cities, states, tribal nations, businesses, schools, institution of health and culture in support of climate action promoting leadership of non-federal participants together with others around the world (Americaisallin 2021).

Maryland has 160 entities working together toward the goal of reducing US carbon emissions by half in 2030, and net zero by 2050 to meet the obligations of the 2015 Paris Agreement. Maryland Climate Change Commission goals exceed the Paris Agreement by planning to attain net zero greenhouse gas emissions in 2045. Maryland's individual participants are continuing to build climate resilience and could further benefit from design leadership resource coordination at the state level. Each one of these participants may have specific design strategies related to their organizational needs, however, innovation is more likely to occur once these design methods are formalized.

Data collection measuring results of incorporating design strategy when identifying sources of climate impact is necessary for recognizing the benefits design practitioners can provide to public organizations and private firms. Framing complex climate change issues requires design practitioners to understand the implications of large data sets representing defined scientific conclusions about climate change. A strategic design approach using commonly understood design methods can be used to generate multiple viable service or product prototypes to develop at scale. Large data set collection and case studies at the state level led by both designers and scientists would need to be coordinated and overseen formally by individuals from design disciplines (graphic, industrial, architecture, urban, interior) and environmental science disciplines taking into consideration emerging technologies such as artificial intelligence. Argentina's BA Climate Action is an example of applying design policy and methods to a large-scale data project resulting in a solution for climate change (OECD-OPSI, n.d.). This open data platform, launched by the Buenos Aires City Government, captures data related to energy efficiency, sustainability and waste management policies to address climate change in Buenos Aires. Multiple stakeholders participated in this project including civil society organizations, environmental experts and private citizens.

In Maryland, the Rockville 2040 Comprehensive Plan consists of environmental policies to guide the city's growth, development, and quality of life over the next twenty years (City of Rockville 2021). The process used to devise this Comprehensive Plan was co-designed by the City Planning Commission and public citizen engagement. The Environmental Report (2015) was co-designed by the city's Environmental Management Divisions, Community Planning and Development Services Department, and city departments and external agencies. Data analysis included geographic information systems (GIS) adopted strategic plans, master plans and capital improvement programmes. Design methods are critical for integrating the concluding outcomes of the city's environmental and sustainability commitments, and tackling climate change as one of these priorities. Elements of the designed plan include watersheds, streams, wetlands and water quality; floodplains and dams; soils and steep slopes; forests and tree canopy; wildlife habitat; environmental hazards; air quality; energy efficiency and generation; and green buildings. This report provides the city with a comprehensive strategy to address climate change, and contains design threads linking the various sub-parts to arrive at specific solutions (City of Rockville 2015).

Design Brief for Maryland's Most Important Element: Water

Maryland's landscape embodies mountainous regions in the western part of the state and coastal regions in the east. Due to the large area of the Chesapeake Bay and the watershed terrain, water covers 22% of Maryland or 6990 miles (USGS 2018). The Chesapeake Bay is a significant natural waterway resource for the state, and provides a source of beauty, natural habitat, recreation and environmental education for residents and visitors. The Bay and its tributaries have increasingly become vulnerable to climate change causing water temperatures to rise over the past thirty years by one degree Celsius with sea levels expected to rise an additional 1.3 to 5.2 feet over the next century, causing an increased frequency of severe weather events negatively affecting communities and life in the surrounding the natural habitats (NOAA Fisheries 2025).

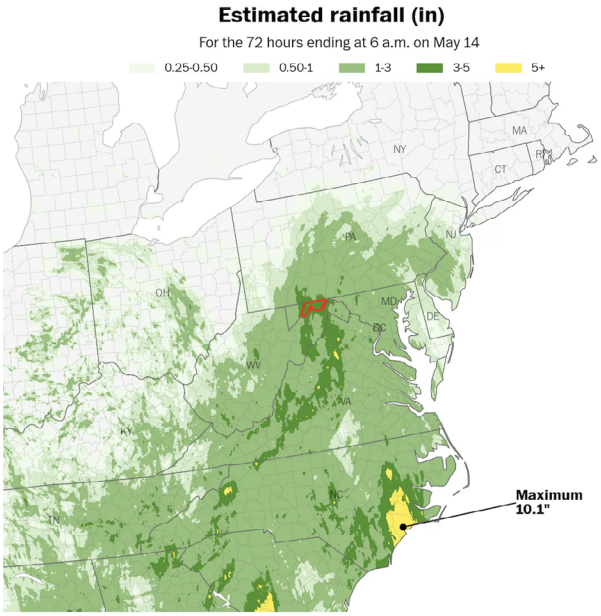

Figure 2: Allegany County, Maryland, outlined in red, received 3-5 inches of rain between 12-14 May 2025 causing the most severe flooding in Maryland's history. Credit: NOAA

In May 2025, Allegany County experienced one of the worst floods in the state's history caused by flash flooding in the town of Westernport, Maryland. The Potomac River from West Virginia to Washington, DC overflowed with five to ten inches of rain caused by an atmospheric river. The term atmospheric river refers to water vapour transported in narrow areas like rivers running along the ground, and cause extreme rainstorm events in the US, Europe and South America (UCSD 2015). Atmospheric rivers can generate more than ten times the volume of water in the Mississippi River (Sublett 2025). The threat of this type of weather event and changes observed in the natural world due to climate change present an adaptable and urgent call to action by design practitioners. In this recent example, immediate collaboration between emergency responders, community organizations and public service providers with design for climate expertise would have not only provide critical supports to individuals in crisis, but also begin to assess the initiation and effectiveness of rebuilding the physical environment while preserving the fabric of a community after a disaster.

Design practices have the creative flexibility to imagine how to adapt the built environment and needs of consumers to slow the pace of climate change. A designer's role and decision-making capacity within any organization carries with it the capability to mitigate environmental impacts when developing a design brief leading to design development stages of products and services. A design brief should outline tangible goals and outcomes while considering climate change and environmental sustainability in every stage of the design process (Morice 2024). Design policies for Maryland need to specify guidance about how any project, whether for the public or private sector, directly contributes to the US carbon emissions reduction by half in 2030, and net zero by 2050 as outlined in the 2015 Paris Agreement. The goals of the Maryland Commission on Climate Change provide a guide to achieve Maryland's climate goals to reduce greenhouse gas emission by 60% from 2006 levels by 2031, and to achieve net-zero emissions by 2045 (MDE 2023). If the Maryland Department of the Environment is responsible for producing the plan to achieve the state's greenhouse gas reduction goals based on a government-wide approach (MDE 2023) and a transition from using fossil fuel-based energy and products to alternative clean energy sources, a design-centred approach to decarbonize the state's economy is necessary to reach these goals. Design-centred approaches to developing environmentally compliant innovative, scalable results in the sectors of the built environment, transportation and business/industry are key to achieving Maryland's net-zero emissions goal.

The independent state design council would function with responsibilities similar to design councils in other countries around the world by developing design policies with climate change as a core premise using the expertise of recognized design fields and related specializations of graphic, industrial, architecture, interior architecture, services, and fashion. Peer review of design briefs and design policy initiatives by representatives from design practice and climate science would confirm the design industry's commitment to the reduction of carbon emissions. As an example, The Bureau of European Design Associations (BEDA) is a not-for-profit association of more than 50 design organizations across 28 European countries including publicly funded design organizations, design professional

and trade associations who promote design nationally and regionally as a key driver for sustainable innovation, societal transformation, and planetary well-being. BEDA represents and advocates for design as a method in everything from products and services to policy making and systemic change. Their MADres Programme develops a Living Design Policy Framework – a flexible, adaptive model that equips governments and institutions to integrate design into national and EU-level policy agendas (BEDA 2025).

Design for Climate in Maryland: Strengths and Challenges

The current strengths and challenges facing efforts to align Design for Climate in Maryland with the Maryland Commission for Climate Change are currently emerging. At this time, Maryland is facing significant challenges related to interaction with the federal government associated to climate change and changes in the employment rate. Between January and August 2025, Maryland lost more than 15 000 federal jobs, the most federal job losses of any state in the US, as well as federal funding which supports some state environmental programmes related to climate change. Federal job losses and a government shutdown have caused some shifts in the state's economy and created a time of general economic uncertainty in the region (Maryland Matters 2025).

It may be possible to provide opportunities for design skill training as these skilled government workers re-enter different sectors of the work force. In the near term, it is most likely the design education programmes in Maryland's higher education institutions along with research programmes through the Smithsonian Environmental Research Center Coastal Carbon Network can provide an ecosystem of collaborative design-led projects and initiatives to identify how design policies can align with the Maryland Commission on Climate Change (Smithsonian 2024). The interaction between individual state's climate change programmes in the US Northeast coastal region and design education programmes similar to Rhode Island School of Design's Nature-Culture-Sustainability academic concentration can serve as a design focused model. This model can serve to establish similar academic programmes for conducting design research focused on climate change and develop relevant design for climate case studies. Collaboration among all design professional organizations across every design discipline, prioritizing climate and sustainability, would establish design leadership while developing design for climate policies in Maryland.

A key foundation for further development of design policy in Maryland is the understanding of how design organizations throughout the world develop design for climate policies at a local and national level while measuring the outcomes related to these historical and ongoing efforts. Awareness of design management and design leadership disciplines in public/governmental and private organizations along with training non-design professionals is essential for climate change related innovations to emerge and provide increased benefits related to health, quality of life and long-term sustainability of our planet. Design may not be able to solve all of the problems presented by climate change, but it has proven to be a catalyst to respond to emerging issues in which observation, problem identification, cross-disciplinary collaboration, imagination, creativity and innovation can make tangible solutions to seemingly intractable environmental challenges. In the words of Rachel Carson:

"The balance of nature is not a *status quo;* it is fluid, ever shifting, in a constant state of adjustment. Man, too, is part of this balance. Sometimes the balance is in his [her/their] favour; sometimes – and all too often through his own activities – it is shifted to his disadvantage" (Carson 1962).

Design can offer a balance in support of nature to reveal what our planet needs to regenerate and sustain the important ecosystems for future generations.

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Applying Systemic Co-design Methods for Transport Transitions at City Scale

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Abstract

This positioning paper introduces the *Inspiring Futures for Zero Carbon Mobility* (INFUZE) project, which applies systemic co-design methods to support city-scale transport transitions. INFUZE addresses the UK's focus on car ownership and technology-led decarbonization and explores how citizens, providers and policymakers can co-create alternative mobility futures. The project is grounded in Meadows's leverage points and extended through the PEKEM framework (Philosophy, Emotions, Knowledge, Experience and Material agency). The collaborative research integrates participatory design, systems thinking and value-sensitive approaches, linking to understanding change, solution modeling, impacts and trials to generate new insights into physical and cultural change and developing a new 'participatory mobility science'.

Keywords: Co-design, decarbonization, participatory mobility science, sustainable mobility, systemic change.

Research Context

As the UK struggles to decarbonize its transport, the INFUZE project pioneers a citizen-led system co-design approach that aims to disrupt car ownership and reimagine how we get around our cities together. The UK drives 252.9 billion miles (Department of Transport 2025) and spends GBP 116 billion per year on owning, maintaining and insuring cars – more than is spent on food and clothing combined (National Audit Office 2024), highlighting its deep dependency on the system of *automobility* (Urry 2014, 25). Since 2015, domestic transport has become the most carbon-intensive with the sector only achieving a 1% reduction in 2022/2023 (Department of Transport 2024); accounting for 29% of all UK carbon emissions.

The UK government's net-zero pathway to 2050 prioritizes the transition to electric vehicles (EV) as the main strategy for decarbonizing transport (Department for Energy Security and Net-Zero 2025). Nevertheless, whole-systems analysis shows that the narrow focus on electrification and technological solutions is insufficient to meet these ambitious targets and will also require demand reductions and mode shift (Marsden 2023). Moreover, this narrow strategy overlooks the broader social, environmental and urban challenges it creates. Projections estimate an extra 10 million vehicles on the road from the uptake of Electric and Autonomous Vehicles (AV), leading to a 54% rise in road traffic by 2060 (Institute of Policy Research 2021). This increase in traffic intensifies the demand for land, reduces the liveability of our cities and continues the path of car dominance in our public realm.

The causal relationship between domestic transport and health, social, and economic inequalities is well documented. Traffic-related air pollution affects everyone; it has a disproportionately adverse impact on vulnerable groups – such as children, the elderly with pre-existing conditions and ethnic minorities – particularly those living in areas where access to green space is limited (Buzzelli and Jerrett 2007, 197). In its pathway to net-zero by 2050, the UK government has prioritized the transition to electric vehicles (EV) as its preferred strategy for decarbonizing transport. However, technological adjustments to the existing system are counterproductive to driving meaningful social and environmental change. How will UK cities like Leeds accommodate an extra 100 000 cars on their roads and streets under such a policy direction and at what cost to people, place, and planet?

Leeds City Council (2025) has recognized that such a future is both unsustainable and undesirable. Its *Connecting Leeds Transport Strategy* sets out an ambitious vision to transform Leeds into a city where you don't need to own a car to get around. To achieve this vision, the strategy focuses on six 'big moves': decarbonizing transport; creating healthier streets, spaces and communities; transforming the city centre; enhancing public transport; delivering a mass transit system and adopting new smart technologies. A key commitment in delivering this transition is the active participation of citizens and businesses from across the city to deliver change and to capitalize on the opportunities that arise through engagement and collaboration in pursuit of a shared vision.

Despite these moves, there is a gap where collaborative and systemic design research can better act as a bridge between policy ambition and the realities of real-world mobility choices and behaviours.

Our Conceptual Framework: People in Systems

INFUZE is grounded by Meadows's (1999) concept of system leverage points which identifies places within a system where interventions and their effectiveness can produce change. Interest in deeper leverage points has grown among researchers and theorists, emphasizing the need for transformative approaches to address complex systemic challenges. The following articles provide important context for this discourse and form the foundation for our conceptual approach.

Meadows (2014) outlines fourteen principles for engaging with system redesign. These include: listening to the wisdom of the system, surfacing mental models, understanding systemic behaviours, prioritizing significance over measurability and adapting to emergent outcomes. Abson and Lang (2016, 30) extend Meadows's hierarchy by identifying four system characteristics: parameters, feedback, design and intent. Critically, they argue that policy interventions typically focus on shallow points and call for deeper engagement to address the underlying causes of unsustainability, through design and intent. Jones (2014) situates design research within this systems foundation, arguing that design methods must evolve to tackle the complexity of socio-technical systems. This approach integrates systems thinking with participatory and reflective design practice, providing a conceptual bridge between systemic leverage and design-led transformation. Here, the introduction of technology-based interventions – like EVs – to address the UK's decarbonization challenge clearly represent a shallow leverage point and therefore offer limited effectiveness in driving transformation change.

Bolton (2022, 2435) examines Meadows's hierarchy in further detail and how it is applied in sustainability governance, illustrating the constraints and influences within public decision-making. They demonstrate why policymakers often concentrate on shallow leverage points, while emphasizing the benefits of a *one-deeper* approach to drive meaningful change in response to sustainability challenges. Nerland et al. (2025, 700) stresses when transforming local governance, the importance of paying particular attention to who holds the power structures to understand its system malfunctions. Here, they introduce the concept of 'space of leverage' in the system and propose two key recommendations that align with the collaborative design team's approach: establishing new means for collaboration that integrate system perspectives and a shared vision across all stakeholders.

In *Shades of Co-design* Blomkamp (2024) highlights the incongruence in how co-design is adopted and applied, while recognizing that it often means different things to different people and across disciplines, and scope and resources can vary significantly between projects. To help researchers reflect on these challenges, especially those engaging in participatory action research, Blomkamp poses three questions: how big is the co-design? (scale); how deep is your co-design? (level) and how wide is the co-design? (extent of design). To evaluate the depth of co-design, Blomkamp provides a matrix that cross-references components found within Arnstein's (1969, 217) ladder of participation against four forms of knowledge acquisition: lived experience, practice wisdom, research evidence and cultural knowledge. These questions and self-assessment tools are not only pertinent to design teams but even more so for trans-disciplinary research teams, where diverse experiences and assumptions related to co-design – may complicate the integration and development of a shared, coherent understanding of co-design and its consistent application.

While Blomkamp focuses on the processes and structures to enable meaningful co-design practice to flourish, Ives (2019, 208) invites us to shift our perspective inwards and to consider how such structures influence an individual's receptiveness to system change. Ives observes how "inner worlds" often shape our human experience through the systems and structures we design, experience and inhabit; physically, socially, culturally and mentally. He calls for greater recognition of the overlooked potential of embedding a deeper "inside-out" approach to sustainability and asks, "how could inner life be approached in sustainability science?" This question is equally relevant for transport policymakers and planners – to ensure future policies are purposely designed to be in tune with inner values and beliefs of citizens.

Reconnecting society with nature, he argues, requires leveraging five types of connection – the material, experiential, cognitive, emotional and philosophical – echoing Meadows's deeper leverage points and forming a conceptual framework that INFUZE advances through design across policy, systems, services and products.

Connecting People, Values and Change

The conceptual framework being adopted by the INFUZE team builds on Ives's thinking by establishing the conditions, methods and tools necessary, applied within a design methodology, to understand the system problems and co-create preferable futures. We build system knowledge by starting with deep leverage points: Philosophies, Emotions and Knowledge, and then moving to Experience Design and Material Agency (PEKEM). PEKEM serves as our conceptual framework, positioning human, cultural and emotional dimensions at the forefront of sustainable mobility futures and linking, at different levels, to our propensity to change as well as the societal readiness of transport systems. Understanding how citizens and communities engage with possible futures requires systematic and equal attention to the five interrelated dimensions of PEKEM – as these factors shape how people imagine, evaluate and act upon transformative possibilities.

- **Philosophy, values and beliefs**: these represent our openness to change and include individual and group values, principles and worldviews. They capture our deeply held commitments and can shape and inform how we respond to future missions and challenges such as health, sustainability and equity.
- **Emotions and feelings about the future**: these point to our willingness to act and describe our emotional responses to potential changes, ranging from optimism and hope to fear and resistance. They influence our acceptance of new experiences and readiness for action, often informed by our social norms and our physical and media environments.
- **Knowledge, opportunities and risks**: these highlight our decision-making clarity and show our awareness and understanding of choices, benefits and risks associated with different decisions and futures. They help us clarify choices, reduce uncertainty, and share preconceptions and can even change our opinions if communicated well.
- **Experience including our lived and practical realities**: these show our ability to imagine meaningful futures and can describe our personal or household routines, constraints and past experiences. They shape our perceptions and our current behaviour but can also be used to help us imagine more practical, inclusive and delightful futures if grounded on new knowledge and inspired by deep connections to our philosophy and values.
- **Material change, agency and resources**: this reflects our capacity to make change in our lives and affects our ability to act, which can be determined by our resources, tools and wider support systems. Without real agency even willing people cannot change. Change is not just physical and technological but also cultural, political, legal and economic.

Together with "triple-loop learning (Tosey, Visser, and Saunders 2002, 293) and value-sensitive design" (Friedman 1996, 17) we advance our collaborative work beyond shallow interventions and consultations to consider our openness to change, willingness to act, decision-making clarity, ability to imagine meaningful futures, and our capacity to make change at urban, neighbourhood and household level.

Introducing the INFUZE Project

INFUZE is a transdisciplinary project to encourage people in Leeds to design and try alternatives to private vehicle ownership. Supported by a £8 million Engineering and Physical Sciences Research Council (EPSRC) programme grant, INFUZE is a five-year research project led by the University of Leeds with the Royal College of Art (RCA) and Lancaster University. The team is supported by thirty-one partners including public bodies such as Leeds City Council, West Yorkshire Combined Authority, the Department of Transport, third-sector charities and private consultants and service providers.

Rather than asking, "can you live without a car?" The central question guiding the INFUZE team is: "what would a world where people did not need to own their own cars look like?"

The primary aim of INFUZE is to shape a new "participatory mobility science" to spark systemic changes in mobility through co-design. As noted above, a strategy of electrifying the vehicle fleet neither meets carbon goals nor does it enable a wider transition in society to more positive travel futures. The research project aims to address these gaps to explore whether genuinely distinct pathways can be built with people, providers and politicians. To fulfil the vision established above we set out seven key research objectives which include three collaborative design challenges:

1. Co-design with communities and stakeholders a set of vision-led approaches to building mobility systems that provide a positive alternative to car ownership.
2. Develop new tools and conceptual models to understand the propensity to shift mobility ownership to mobility access taking account of new mobility service characteristics.
3. Change how mobility transitions are researched, developing a new approach to participatory mobility science for change.

INFUZE is being delivered through a programme of four interconnected and interdependent work packages (WP): Co-design; Understanding change potential; Building design solutions and Trial delivery, evaluation and governing change (see Image 1). Structured around an inclusive and participatory design process, a cycle of 'listen, vision, build, and change' is repeated through the five years of the programme grant.

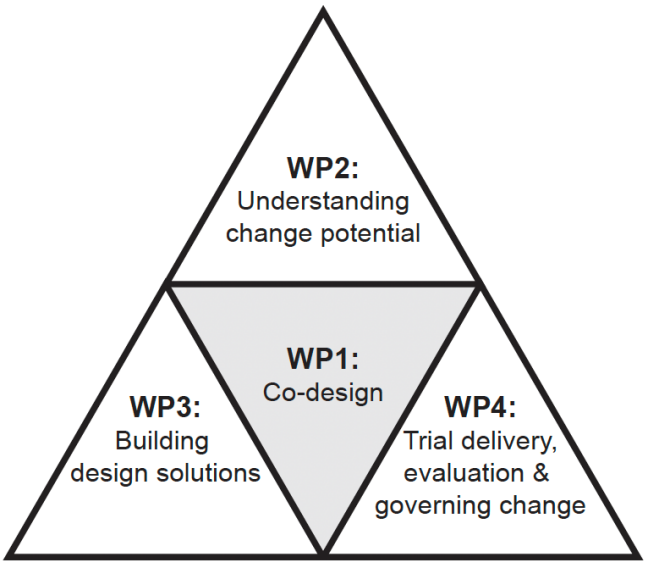

Image 1: INFUZE work packages.

WP1 Co-design

WP1 brings together the research expertise of the RCA's Intelligent Mobility Design Centre (IMDC) and Lancaster University's Centre for Social Futures (CSF). The CSF was founded in 2015 by John Urry and Linda Woodhead. Its current research activities are situated within the themes of digital and material, culture and creativity, mental health and well-being and environmental and social futures. Past research enquiries and conferences within the Environmental and Social Future have explored themes such as *Everyday Futures, Mobile Utopias* and *DecarboN8*. The projects *Cumbria 2038* and *Bridging the Gap* tested alternative approaches to deploying reflective design in planning. One of the key learnings was that the current separation between expert visioning and community visioning was evident, highlighting the need for greater integration in co-design processes.

The IMDC was established in 2016 with foundational support from Hyundai-Kia to create a transdisciplinary centre exploring, experimenting, prototyping and evaluating new mobility and automotive transitions via the synthesis of design and research. It integrates design and technology with insights into people and the social, environmental and economic context to enable a 360-view on the design of future mobility. The IMDC is organized into three distinct yet complementary studios enabling a multifaceted perspective on mobility design: The Automotive Transitions Studio, The Humanizing Technology Studio and The People & Places Studio (P&PS).

Over the past decade, the IMDC has undertaken a wide range of collaborative research projects spanning investigative themes such as *Driverless Futures, Streets for Diversity* and *Our Future Towns*. *Our Future Towns* project – led by the RCA in collaboration with the Transport Planning Society, Chartered Institution of Highway Engineers and local councils – served as a foundational initiative for the IMDC's People and Places Studio. Through engagement with three rural communities, the project developed a set of participatory design tools and methods to help citizens listen, learn, imagine and lead change around mobility, spatial and town futures. Its findings demonstrate the value of co-creating shared visions rooted in local values, emotional insights and lived experience – highlighting how meaningful change can emerge from community participation not just from predictive systems, infrastructure or policy (Phillips 2021). The learnings from *Our Future Towns* directly informed INFUZE's systemic co-design approach and acted as a small-scale testbed for the human-centred methods now being applied at city scale.

The co-design work package serves as the project's spine, enabling networked connectivity across all work packages through a continuous process of integrating, synthesizing and sharing insights. The team seeks to address the uncertainties of generating mobility system transformations by developing a new 'participatory mobility science' – a collaborative design approach that seeks to embed citizens and stakeholders in the process of integrating creativity and equity into the scientific models of transport planning. The co-design work is structured around an annual cycle of co-produced design research, implementation and reflection, and includes a series of Creative Assemblies, Visioning and the development of a Toolkit.

In the first year, the authors aimed to position citizens as equal partners – co-creators of future mobility systems – grounding the process in their shared values and knowledge, rather than in journey maps or new technologies, to explore how they want to move, feel, and live in the future. In response to the initial call to action, they established a creative assembly to explore citizens' individual and communal philosophies, values, knowledge, experiences and agency for change (see Image 2).

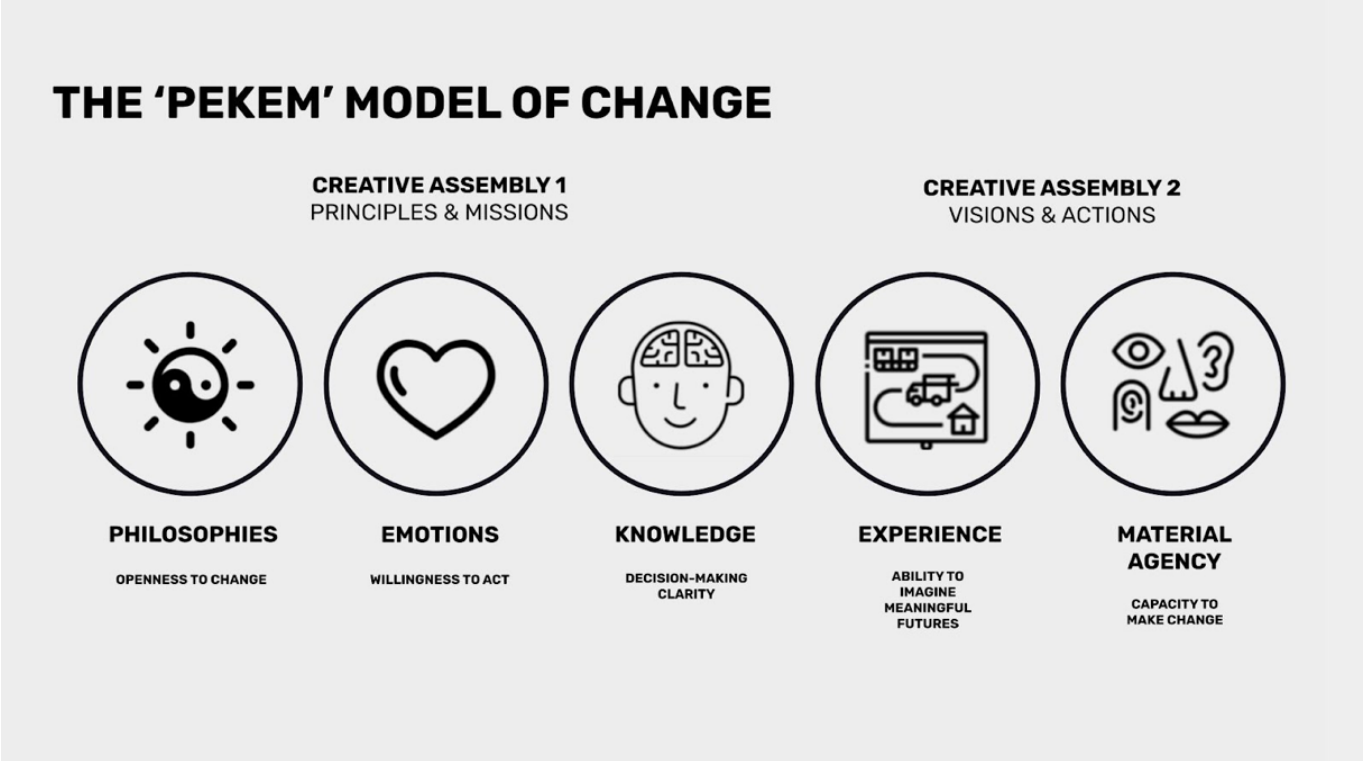

Image 2: The conceptual framework.

The authors brought together a consistent group of 25 citizens from across the city for two connected Creative Assembly events hosted at Leeds City Museum. To support a process of active listening and mutual learning, they developed a formative philosophies, values and emotions card set (see Image 3). Together, the Assembly shared their hopes and concerns and identified the risks, opportunities and missions for the future of their city. This activity included the exploration of the risks, opportunities and missions people share when interrogating desirable (utopian) and undesirable (dystopian) futures.

Image 3: Examples of philosophy cards.

Visioning has engaged participants and stakeholders in the design research process through two steps: imagining and changing. This creative process builds on the places and journeys that matter to people, as well as their values, skills, loves, fears, frustrations, and beliefs about the future. Groups worked together to develop a series of speculative visions based on the assembly's guiding principles and emotional design needs. This ongoing process is contributing to the co-creation of citizen-led visions and principles for changes to Leeds's mobility system.

A key output will be a new 'participatory mobility science toolkit' to transform the approach to transition planning. The Toolkit is evolving as a live, iterative resource across the whole project as the authors learn about how to co-design new mobility futures. Its finalized form will contain a portfolio of online resources, videos, visuals, guidance on making data and modeling accessible, and engaging citizens in trial design and delivery for change. The engagement activities throughout the project will also help promote wider adoption through active advocacy, increasing in intensity as the Toolkit matures.

The shared mental model developed by the Assembly is now being disseminated across the INFUZE research team and its partners, providing a set of principles and missions that will anchor the next phase of work – a phase in which the team will engage more deeply with the Assembly, in community settings and involve citizens who wish to rehearse the future through proto-practice experiments.

Why this Work Matters

Situated in transport policy and design, this novel approach is the first of its kind to apply the systemic use of deep, medium and shallow leverage points in a real-world context using a design methodology. This claim is supported by a scoping review, which identified extensive theoretical discourse but, critically, found no demonstrable examples of its application in policy or design context beyond the RCA and INFUZE. Furthermore, examples of citizen participation where power and influence are afforded within transport planning and public policymaking remain rare (Pappers, Keseru, and Macharis 2020, 13).

Although in its first year, as the research, learning and toolkit evolve, its delivery will serve as a dynamic case study for transport policymakers, planners, service providers and designers to re-evaluate how systemic co-design methods can be applied to support transport transitions at city scale.

Author's note: The original text has been submitted to ChatGPT for the sole purpose of grammar, language and clarity review.

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Building a Regenerative Framework for Climate-engaged Design Practice: Understanding Structural Barriers and Cultural Apathy in Australia

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Abstract

This paper examines the cultural, structural and policy conditions shaping climate action within the Australian design industry. Conducted by Design Declares Australia (DDA), the study integrates survey data, literature review and policy analysis to explore how designers navigate the gap between environmental intention and implementation. Findings reveal strong ethical alignment with regenerative design principles but limited translation into practice due to client expectations, budget constraints and insufficient systemic support. The study identifies a critical need for clearer frameworks, measurable tools and institutional legitimacy to empower climate-positive practice. In response, the proposed Design Declares Australia framework establishes five pillars: Enabling Conditions, Cultural Transformation, Engagement and Accountability, Systemic Advocacy and Education and Epistemic Integration to bridge motivation with action. Central to this model is the integration of Indigenous knowledge systems, reframing regeneration as a relational and place-based practice. Together these strategies aim to position Australian design as a catalyst for ecological and cultural resilience in a regenerative future.

Keywords: Attitudes, Australia, climate action, design industry, regenerative design.

Introduction

Today's design industry is broad, encompassing a wide range of disciplines including industrial, graphic, digital, fashion, interiors, architecture and experience design. As an industry, it holds considerable power in shaping the built and digital environments that impact global consumption, resource extraction and waste management. However, despite the increasing urgency of the climate crisis, the industry has been slow to embrace sustainable and regenerative practices. This resistance is not from individual inaction but from a complex network of structural, economic and cultural barriers. Understanding and addressing these hurdles is critical for transforming design into a catalyst for climate justice and ecological resilience. Design Declares! is a climate action movement that comprises visual communication, digital, industrial, service and interior design. According to Jobs and Skills Australia (2025), there are approximately 81 300 designers employed across these specific disciplines, categorized in the following groupings: graphic/web/illustration; industrial design; and interior design. Multiple chapters exist worldwide, with the most notable located in the United Kingdom where the movement was founded in 2022. Several country chapters have gained significant support from their design communities, including Ireland, where climate action has been effectively integrated into high-profile design events in collaboration with the Institute of Designers in Ireland (IDI). However, other chapters have been slower to develop, with fewer signatories and less public support for the movement. Despite these challenges, there is potential for growth and increased backing within the design industry. Design Declares Australia was established in 2024, and an advisory board was appointed to strategize on embedding and implementing climate action within the Australian design sector.

This research study examines the cultural and operational context of how the Australian design industry responds to climate action, with a particular emphasis on how policy and governance frameworks affect designers' ability to adopt regenerative practices. Initiated and conducted by Design Declares Australia, the study primarily focuses on the behaviours and attitudes of designers, assessing both the positive and negative aspects of embracing a regenerative mindset in their business practices. By exploring the intersection of policy, design culture and professional norms, the research provides insights into how national and local policy contexts can support or hinder a regenerative design agenda. It incorporates both primary and secondary research methods to explore the cultural context of regenerative design across Australia. The findings will inform a strategic framework and a set of recommendations for Design Declares Australia, providing policy-relevant strategies for embedding ecological responsibility into the design sector. It aims to identify the obstacles to fostering a thriving regenerative design culture ecosystem in Australia and develop a strategy to enhance the national climate action identity.

Image 1: Design Declares! is a climate action movement that comprises visual communication, digital, industrial, service and interior design.

Resistance to climate action is not new. At the heart of this resistance lies a fundamental contradiction: while many designers want to contribute to climate solutions, their efforts are often constrained by client demands, budget limitations, and ingrained professional norms. Warren-Myers et al. (2024) highlight this tension in architecture, where practitioners frequently encounter institutional and market-based obstacles that prevent the integration of climate-responsive strategies. These obstacles include limited client awareness and regulatory ambiguity but also a lack of accessible tools for regenerative design. The result is a persistent gap between climate-conscious rhetoric and business-as-usual practices. Economic structures further embed this inaction.

Glicksman (2010) states in his analysis of industry resistance to environmental regulation that profit-driven models often focus on short-term gains over long-term ecological responsibility. In design, this manifests in prioritizing aesthetics, speed and cost-efficiency over sustainability. Clients rarely commission work with environmental performance as a core focus and designers operating in competitive markets are discouraged and deterred from proposing climate-positive alternatives that may increase project complexity or cost. Sustainable features are often treated as optional add-ons rather than as integral components of the design brief. Cultural dynamics within the design profession also play an important role. The industry's appreciation of innovation, novelty and trends can oddly hinder systemic change.

As Speed (2024) notes, the design field's obsession with measurement and objectivity often fails to account for climate action's regenerative and relational dimensions. This leads to superficial interventions, such as using 'green' materials or 'greenwashing', rather than deep engagement with the social and ecological systems that design affects. Similarly, Jo Barnard (2025) criticizes the tendency to treat regenerative design as a branding tool, something to be proclaimed rather than practiced. She argues that regenerative design must be internalized as a mindset and operational paradigm, not externalized as a symbolic label. This reflects broader issues in the design profession where climate action is often adopted as a performative gesture rather than a substantive shift. Over the last few decades, awards, publications and educational institutions often reinforced this dynamic by celebrating visual impact over environmental performance or social equity. Barnard (2025) underscores this, warning that without rigorous self-reflection, designers risk perpetuating ecological harm under the guise of progress. This cultural apathy is compounded by the legacy of modernist thinking, which has a tendency to give precedence to human control, technological mastery and linear progress. Such paradigms are at odds with ecological worldviews that promote interdependence, nonlinearity and resilience. Petrescu (2024) advocates for harnessing design research to imagine alternative futures yet acknowledges that many designers lack the frameworks or vocabularies to engage meaningfully with climate science or systems thinking. Interdisciplinary collaboration is often cited as a solution but the siloed nature of design education and practice limits the integration of ecological literacy into mainstream workflows.

Despite these challenges, there are signs of transformation with movements such as regenerative design, post-growth architecture, and speculative climate design gaining traction. Nowaki and Foissac (2022) advocate for "regeneration in action", calling for research and practice that move beyond sustainability toward ecological restoration and resilience. Similarly, Murphy et al. (2025) propose the Ripple model: a scalable, inclusive and transdisciplinary approach to climate-engaged design research. Funded by Creative Ireland, the project focused on climate action through the co-design of green space and was piloted in a disadvantaged housing estate in Ballina, County Mayo (Ireland) aiming to bridge the gap between climate knowledge and local action. These initiatives demonstrate that alternative models are possible and already emerging, though often at the margins of the industry.

Image 2: A workshop at the World Design Congress London 2025 using Design Declares Climate-Action Cards as a facilitator for initiating change.

Australian Initiatives and Cultural Context

In Australia, professional design advocacy is primarily led by two professional bodies and organizations: the Design Institute of Australia (DIA), originally established in 1947 and the Australian Design Council (ADC) which was launched in 1958 and formally re-established in 2020. Both recognize the environmental responsibilities of design and have embedded sustainability principles within their frameworks. The DIA Code of Conduct positions environmental mindfulness as an ethical obligation, encouraging members to reduce ecological harm and integrate principles of conservation and circularity in their practice (Design Institute of Australia 2023). Similarly, the ADC places sustainability at the core of its Design Impact Pillars. Its second pillar, 'Planet: Designing for Environmental Sustainability and Circularity' challenges designers to evaluate how their work reduces impact and supports Australia's transition toward a regenerative economy (Australian Design Council 2024). At first glance, the Australian support landscape for design and climate-action looks promising.

The Australian Government has also begun to embed design within national environmental agendas. In 2022, the Department of Climate Change, Energy, the Environment and Water (DCCEEW) commissioned RMIT University to lead the *Enabling Design for Environmental Good* project, in partnership with Arcadis and One Planet Consulting. The project defined eco-design as "any form of design that minimizes environmentally destructive impacts by integrating itself with living processes" and expanded this to incorporate regenerative design and zero-waste principles (Lockrey et al. 2022). Focusing on textiles, building, plastics and electronics, the report identified ten cross-cutting levers for embedding eco-design into policy and practice. These included adopting a national Eco-Design Strategy, revising product stewardship frameworks, supporting reuse and repair, raising standards, funding innovation, and leveraging procurement. The study concluded that systemic transformation, rather than voluntary measures, is required to achieve environmental good. This is in part due to product life cycles being governed more by policy and market structures than individual designers.

In addition to these government and advocacy initiatives, the Australian Good Design Awards have normalized sustainability within its professional recognition capacity. Since 2007, the Australian Good Design Award for Sustainability has celebrated projects that integrate circularity and longevity into design practice. In parallel, the Concept Design category now assesses entries against the United Nations Sustainable Development Goals, signaling the mainstreaming of regenerative and socially responsible criteria (Australian Design Council 2024).

Australia's major design festivals have also adopted sustainability as theme in recent years. Melbourne Design Week 2024 explored *Design the World You Want* through the pillars of ecology, ethics and energy (National Gallery of Victoria 2024), while the 2025 iteration emphasized *First Peoples First*, health and wellbeing, and environmental impact, calling for projects that "heal, replenish, and enable life." Similarly, Sydney Design Week 2024, themed In *Between Worlds*, featured keynotes on sustainability and belonging, positioning design as a tool for ecological and social repair (Powerhouse Museum 2024). In parallel to these initiatives, Sydney Climate Action Week has emerged as a major interdisciplinary platform linking design, communication and climate engagement through events on ethical branding, low-carbon digital design and anti-greenwashing strategies (City of Sydney 2024).

At the policy level, the Australian Government's Interim Report on Australia's Circular Economy: Unlocking the Opportunities (2025) acknowledges slow national progress toward circularity, citing inconsistent regulation and fragmented policy. The report highlights design's critical role in reducing material consumption, extending product lifespans, and enabling reuse and repair (DCCEEW 2025) while stressing the need for coherent national strategies that integrate design as a central mechanism for change. Complementary projects such as Sustainability Victoria's Market Accelerator Grants Scheme (2025) demonstrate regional leadership by funding recycled material innovation, bridging the gap between design-led research and commercial application.

Design education has played an important role in supporting the transition toward regenerative practice through sustainability or other associated agendas. Victor Papanek's seminal work *Design for the Real World* (1972) argued the case for designers to step up to their responsibilities to address the real needs of people and planet. From personal experience as an educator, sustainable design notably began to permeate design school education in the late 1990s and early 2000s, particularly in industrial design courses. In the years that followed, the emergence and rapid rise of the digital age for education soon became prominent. Fast forward to 2025, and Australian design schools offer an interesting perspective on how sustainability is viewed or embedded as a core component of degree-level education. A notable few have increasingly integrated sustainability and circularity into their curricula. RMIT University has embedded a sustainability major within its Bachelor of Industrial Design and recently launched the Regenerative Futures Institute to deliver short courses in regenerative innovation. The University of South Australia offers a Master of Design (Sustainable Design), and most major institutions include or have embedded sustainability-focused modules/courses within their design programmes. However, it is not widespread across design disciplines. While educational reforms signal a positive cultural shift toward preparing future designers as agents of environmental stewardship, other emerging technologies, such as artificial intelligence (AI), are significantly impacting university curricula. Universities continue to struggle with agility and socio-technological changes, as curricula often reflect what industry wants rather than what industry needs. In this common scenario, sustainability agendas can often slip down the priority ladder and, in some cases, are barely visible within design courses at all.

Recent scholarship has highlighted the centrality of Indigenous knowledge systems in shaping Australia's approach to regenerative design. Rooted in deep relationships with country, reciprocity and intergenerational stewardship, Indigenous worldviews offer holistic frameworks that extend beyond Western sustainability paradigms (Hromek 2019). The Australian Indigenous Design Charter (Kennedy and Kelly 2016) articulates protocols for respectful engagement, emphasizing Indigenous-led processes, deep listening (*dadirri*), community specificity, and cultural accountability, while 'country-centred design' methodologies reframe practice around the agency of land, water and non-human entities (Kelly and Meghan 2019). Institutional initiatives such as Victoria's *Indigenous Design Guidelines* (LXRP 2021) further embed these principles within the built environment, advocating early collaboration with Traditional Owners and co-design approaches that integrate ecological and cultural narratives. By centring Indigenous epistemologies, Australian design can move beyond technocratic notions of sustainability toward regenerative, relational and decolonial practices grounded in respect, continuity and care for country.

Methodology

This study employs a qualitative, interpretivist approach combining a survey, policy scan and literature review to explore the ecology of acceptance and resistance to climate action within the Australian design industry. Developed and distributed by Design Declares Australia, participants were recruited via design networks, climate-action platforms and social media, with particular attention to capturing both engaged and disengaged voices. The anonymous survey focused on participants' understanding of climate responsibility, perceived barriers to sustainable practice and reflections on the role of clients, educators, governments and professional bodies in enabling or obstructing change. It was categorized into four main sections: attitudes and behaviours; barriers and challenges; industry and systemic change; and reflective open feedback. To contextualize the results and themes from the survey, a policy scan and literature review was conducted in parallel across federal and state sustainability frameworks affecting the design sector.

Finally, the research study acknowledges positionality. As designer-researchers engaged as advisors/board members to Design Declares Australia, our proximity to the topic offers both insight and autoethnographic observations on what we have experienced in the pursuit of gathering momentum for our community.

Discussion

The research findings highlight a design sector that is philosophically aligned with climate action yet structurally constrained in its ability to translate these values into practice. There is a unanimous recognition that climate action is both relevant and urgent. Designers broadly understood their work as implicated in environmental and social outcomes, but the translation of regenerative principles remains fragmented, conditional and dependent on external factors such as client demand, budget constraints and institutional support.

While designers express strong ethical commitments to sustainability, the study reveals that climate-positive practice is often negotiated within the boundaries of feasibility rather than fully embedded as standard practice. Many respondents described sustainability as integral to their professional identity but admitted that implementation was frequently compromised by commercial realities. These findings reflect a tension identified by Warren-Myers et al. (2024) and Barnard (2025), where ecological aspirations within design culture often collide with economic and operational limitations. Designers are willing but constrained: motivated by values yet hindered by a lack of systemic and structural enablers.

A consistent pattern emerging across the data is the discrepancy between awareness and action. Designers articulate a moral and professional obligation to address climate change but remain uncertain about how to implement these ambitions. Client resistance, budgetary pressures and limited access to practical frameworks or measurable tools for regenerative design were cited as key barriers. Many participants also highlighted industry apathy within the profession stating the continuous deep-rooted focus on aesthetics, speed and cost-efficiency, leaving limited room for experimentation or long-term ecological thinking. As Speed (2024) notes, this fixation on output and measurement can stifle the relational and restorative dimensions of design, producing rhetorical rather than transformative sustainability outcomes.

The results also underscore that industry-wide leadership and policy support are perceived as insufficient. Respondents consistently called for clearer regulatory guidance, procurement requirements and professional standards that could legitimize and mandate climate action across projects and sectors. At present, climate responsibility is largely treated as a voluntary pursuit, dependent on individual conviction rather than collective obligation. The limited visibility of Design Declares Australia further compounds this challenge, suggesting that while awareness is growing, the mechanisms for engagement and accountability remain underdeveloped.

Regenerative Design as a Cultural Shift

A significant insight is that many designers view regenerative design as an aspirational yet ambiguous concept. It is widely understood as an evolution beyond sustainability, a movement toward creating conditions that restore rather than deplete ecological and social systems. It is clear there is a general maturity to understanding the role of regenerative design, but there also appears to be a disconnect between what designers get taught in design school and the reality they face in their every-day jobs. Respondents commonly described regenerative design as "giving back more than it takes", a philosophy that demands systems thinking, circularity and holistic responsibility. However, uncertainty persists about what this looks and feels like in practice. Some designers express skepticism about the term's definitional vagueness and potential susceptibility to greenwashing, highlighting the need for clearer frameworks, exemplars and measurable criteria. This ambiguity reveals a broader cultural challenge with the need to shift design from a paradigm of human-centred problem solving toward one that is ecology-centred and systemic. Achieving this transformation requires reimagining design not as a discrete service but as an active participant in planetary systems. Doing so entails recognizing that regeneration is both material and relational – it involves restoring ecosystems, reconfiguring social practices, and decolonizing modes of knowledge production and decision-making.

Design education forms the connective tissue between critical thinking and skills into industry, cultivating the next generation of climate-literate designers. Reflecting on over five decades in pursuit of a focus towards socially responsible design in education and practice (Papanek 1972; Margolin 1989; Manzini 2003; Irwin et al. 2015; Barnard 2025), Australian universities are increasingly embedding sustainability and circularity into their programmes. These reforms still remain uneven and often subordinate to emerging technologies such as AI or continuous digital innovations. Embedding ecological literacy as a non-negotiable professional competency would address this gap. Within a potential framework, education should function as both an enabler and a transformer that builds capacity and epistemic diversity through collaborative partnerships between academia, industry and Indigenous knowledge systems.

Integrating Indigenous Knowledge Systems

Within the Australian context, a regenerative design framework must engage deeply with Indigenous knowledge systems. First Nations worldviews inherently embody regenerative principles - interdependence, reciprocity and care for country that predate contemporary sustainability discourses by millennia. Integrating these epistemologies reframes regeneration as an ongoing relationship with place, rather than a technical intervention or symbolic commitment.

Survey responses that emphasized place-based and systems-oriented approaches resonate strongly with Indigenous perspectives, suggesting an intuitive alignment between regenerative design and Indigenous ways of knowing. As Yunkaporta (2019) and Grant (2021) argue, 'Designing with Country' requires humility, reciprocity and the recognition that design is not about imposing solutions but participating in the living systems of place. Embedding Indigenous knowledge into the Design Declares Australia framework would therefore require structural and cultural transformation. This would initiate a more collaborative approach involving co-design and co-governance with Traditional Owners and knowledge custodians.

Such integration could take several forms: establishing Indigenous advisory roles within professional design bodies and collectives; developing co-authored educational resources; embedding 'Designing with Country' principles into accreditation and procurement frameworks; and recognizing Indigenous sovereignty in knowledge production. These shifts would position regenerative design not as a new discipline but as a reconnection to enduring principles of custodianship and balance. In this sense, Indigenous knowledge is not an adjunct to regeneration but its foundation, a reminder that design's ultimate purpose is to sustain the relationships that sustain life.

Towards a Framework for Design Declares Australia (DDA)

A thematic analysis informed the foundation of a Design Declares Australia Strategic Framework by translating diagnostic insights into actionable domains of change. It recognizes that Australian designers are motivated but constrained, seeking legitimacy, resources, and leadership to act on climate commitments. The resulting framework positions DDA as a multifaceted catalyst: building enabling conditions for action, driving cultural transformation within design practice, fostering trust and collective participation through engagement, linking design to policy and governance reform, and embedding regenerative and Indigenous knowledge across learning and professional practice. In the alignment of motivation with structural and cultural support, DDA can move beyond awareness-raising to foster a regenerative design ecosystem that is both locally grounded and globally resonant. The development of a framework for Design Declares Australia should focus on five key pillars:

1. **Enabling Conditions**
   Designers require institutional, regulatory and infrastructural support to move from individual intention to collective action. DDA's framework calls for the establishment of enabling conditions: clear policy alignment, procurement standards and accessible tools for evaluating impact. This includes developing open-access carbon accounting templates, design toolkits and circular material databases. By strengthening institutional legitimacy, DDA can turn voluntary climate commitments into embedded professional norms.

2. **Cultural Transformation**
   The design industry's values, incentives and practices must evolve from a human-centred to an ecology-centred paradigm. The study highlights a professional culture still shaped by aesthetics and efficiency. DDA can act as a cultural mediator, advocating for new metrics of value such as longevity, care and reciprocity while supporting designers to champion systemic change. Initiatives could include storytelling platforms, case studies of regenerative practice and peer-to-peer mentoring networks.

3. **Engagement and Accountability**
   Designers expressed a desire for visible, credible and participatory mechanisms to support climate action. Many fear that signing declarations without demonstrable change risks accusations of greenwashing. Focus required on transparency and community engagement, introducing tiered levels of participation (e.g., sign, act, lead), and creating feedback loops through reflection reports or peer recognition. By building a culture of accountability rather than perfection, DDA can enable partial progress as part of a shared regenerative journey.

4. **Systemic Advocacy**
   Designers operate within economic and political systems that either constrain or enable sustainability. The research indicates that without coherent policy alignment, design-led climate action remains fragmented. DDA's role as a policy intermediary is important: translating national circular economy goals into design-relevant standards, influencing tender criteria and advocating for design's inclusion in environmental and innovation policy. Through partnerships with the Design Institute of Australia, the Australian Design Council and government agencies, DDA can amplify design's policy presence and systemic leverage.

5. **Education and Epistemic Integration: Learning for Regeneration**
   Education is the foundation upon which all other framework pillars depend. It functions not only as a source of skill development but also as a space for rethinking the epistemologies that shape design. By embedding sustainability, circularity, and regenerative design within higher education, DDA can help nurture a generation of practitioners equipped with the knowledge, ethics and systems thinking required for ecological transition. Education must go beyond technical competency, it should cultivate the capacity for reflection, care and cultural awareness.

Integrating 'Indigenous worldviews, systems thinking, and cross-disciplinary collaboration' within design curricula reframes education as a relational process rather than a technical one. Indigenous knowledge systems rooted in interdependence, reciprocity and custodianship of Country, offer models of regeneration that extend beyond Western notions of sustainability. Co-developing programmes with Traditional Owners, Elders, and Indigenous scholars embeds a living understanding of place, context, and responsibility into the design process. This approach positions education as both a cultural bridge and regenerative catalyst, grounding design in local ecologies while resonating globally.

Through these pillars, Design Declares Australia can evolve beyond advocacy into a structured ecosystem of action - one that not only raises awareness but also builds capacity, credibility and cultural confidence for the design sector to lead meaningful climate transitions. The study collectively reveals that while designers demonstrate high ethical commitment to climate action, their ability to translate intention into practice is constrained by inherent, cultural and epistemic factors. The proposed framework for Design Declares Australia builds directly from these insights, positioning DDA as a conduit between governance, industry and education, not simply as an advocacy campaign but as an enabling ecosystem for regenerative design.

The study's key findings are highlighted as eight interconnected themes that outline the barriers, enablers and cultural conditions shaping climate action in the Australian design sector. Each theme corresponds to one or more pillars of the *Design Declares Australia Regenerative Design Ecosystem,* translating insights into practical implications for systemic and cultural transformation.

Proposed Framework of Themes to Enable Implications for Action

- **High commitment but low conversion: Motivation - Action Gap** The study identifies that designers perceive climate action as integral to their identity but struggle to embed it due to uncertainty and limited structural support. This corresponds to the framework's 'enabling conditions' pillar, which calls for clearer pathways, measurable tools, and institutional legitimacy to support individual and collective commitment.
- **Cultural and structural resistance: Advocacy and systemic change**

  The discussion section expands this point by identifying how entrenched professional norms and economic models hinder regenerative practice. Within the framework, this aligns with the 'cultural transformation' pillar, which requires DDA to act as both advocate and educator, addressing procurement, regulation and cultural values that shape the sector's operating environment.
- **Passive engagement and fear of greenwashing: Trust and credibility**

  The survey analysis showed that designers' reluctance to sign DDA stems from perceived reputational risk, informational uncertainty and lack of knowledge. This is interpreted as an issue of legitimacy rather than resistance, suggesting DDA must build transparent communication strategies and community-based learning models where they can also bridge a gap in making DDA more visible on a national level. This reinforces the framework's focus on trust-building and participatory engagement as mechanisms for cultural change.
- **Desire for guidance and resources: Practice-based support** Respondents called for practical tools and exemplars; a finding reflected in a call for frameworks that bridge ambition and implementation. This is situated within the 'enabling conditions' domain but is also supported by 'epistemic integration', which advocates for contextually grounded learning through Indigenous and place-based knowledge.
- **Policy and governance implications: DDA as policy intermediary** Climate action within design is currently voluntary and under-legitimized, pointing to the need for institutional coherence. The Framework's emphasis on DDA as a policy intermediary aligns with the conclusion that leadership and governance mechanisms must empower designers to act within existing sustainability agendas.
- **Integration of Indigenous knowledge systems: Epistemic integration**

  The study introduces a vital new dimension to the framework: the recognition that regenerative design in Australia should be grounded in Indigenous ways of knowing and 'Designing with Country'. This epistemic integration transforms DDA's framework from a technical toolkit into a cultural and relational ecosystem, connecting design practice to long-standing principles of care, reciprocity and custodianship.
- **Fragmented industry culture: Collective coordination** Participants described Australia's design culture as emerging yet inconsistent, with sustainability often discussed more than enacted. This fragmentation underscores the need for cultural transformation and systemic advocacy, where DDA can function as a unifying platform connecting disciplines, professional bodies and policymakers. Strengthening collective identity and shared standards is critical for accelerating sector-wide climate action.
- **Lack of consistent education focus: Learning gaps and capacity building**

  Findings revealed uneven integration of sustainability across design education and professional learning. This aligns with education and epistemic integration, which positions learning as the foundation of regeneration. DDA can address these gaps through partnerships with universities, professional bodies and Indigenous communities to embed regenerative principles, systems thinking, and 'Designing with Country' into curricula and continuing education.

The *Design Declares Australia Regenerative Design Ecosystem* presented in Table 1 demonstrates how each insight from the research directly informs a pillar of strategic intervention. The alignment of survey findings and literature with interpretive themes and framework themes translates abstract barriers into actionable pathways for change. Together, these interlinked components articulate a multidimensional response: from individual motivation and cultural transformation to systemic advocacy and epistemic integration. By embedding Indigenous local knowledge systems as the epistemic foundation of regeneration, the framework moves beyond Western technocratic models of sustainability toward relational, place-based modes of practice grounded in Country. The conceptual model thus provides a scaffold for DDA to evolve from a declarative movement into a structured, adaptive ecosystem capable of supporting behavioural, institutional and cultural change across Australia's design sector.

Framework Pillar	Purpose	Key Strategies	Addresses
1. Enabling conditions	Establish the practical and institutional foundations for climate-positive design.	Develop open-access toolkits, carbon calculators, and regenerative design guides. Create clear pathways for participation (sign, act, lead). Integrate sustainability into accreditation and procurement standards.	High commitment but low conversion: Motivation–action gap Desire for guidance and resources: Practice-based support
2. Cultural transformation	Shift design values from aesthetics and efficiency toward care, longevity, and ecological reciprocity.	Advocate for regenerative narratives through awards, exhibitions and discourse. Embed stewardship and repair into design evaluation and teaching. Foster cross-disciplinary collaboration and collective identity.	Cultural and structural resistance: Advocacy and systemic change Fragmented industry culture: Collective coordination
3. Engagement and accountability	Build trust, credibility, and collective participation for climate action.	Establish transparent communication and peer validation systems. Broaden the geographic reach of DDA to extend outside of major cities into remote and regional areas. Facilitate participatory learning networks and reflection mechanisms. Recognize incremental progress to mitigate fear of greenwashing.	Passive engagement and fear of greenwashing: Trust and credibility
4. Systemic advocacy	Translate sustainability policy into actionable design frameworks and governance alignment.	Advocate for design inclusion in national circular economy strategies. Partner with government to embed sustainability in procurement and regulation. Position DDA as an intermediary linking design, environment and innovation policy.	Policy and governance implications: DDA as policy intermediary Fragmented industry culture: Collective coordination
5. Education and epistemic integration	Build long-term capacity through plural learning systems that merge formal education and Indigenous knowledge.	Embed ‘Designing with Country’ and ecological literacy into curricula. Co-develop programmes with Elders, Indigenous scholars, and universities. Foster lifelong learning and mentoring across education and practice.	Lack of consistent education focus: Learning gaps and capacity building Integration of Indigenous knowledge systems: Epistemic integration

Table 1: The DDA Regenerative Design Ecosystem.

Conclusion

This study reveals that the Australian design sector stands at a crucial moment defined by ethical conviction but constrained by structural apathy. Designers demonstrate strong awareness of their environmental responsibilities yet remain limited by systemic, cultural and institutional barriers that impede meaningful action. Translating regenerative ambition into practice requires more than individual will; it demands coordinated transformation across policy, education and professional governance. The proposed Design Declares Australia framework responds to this need by positioning DDA as an intermediary and enabler, bridging motivation with implementation and advocacy with accountability. Its five interconnected domains: Enabling conditions, Cultural transformation, Engagement and accountability, Systemic advocacy and Education and epistemic integration provide a holistic scaffold for embedding climate action across the sector. Critically, the inclusion of Indigenous knowledge reframes regeneration as relational and place-based, grounding design in the principles of reciprocity and care for Country. As Australia moves toward a circular and regenerative economy, design must shift from reactive sustainability to proactive stewardship. Through this framework, DDA can catalyze a cultural movement that transforms design from a passive observer of environmental change into an active agent of ecological and social regeneration, advancing a national design identity that is both ethically grounded and globally resonant.

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Cultural Design as Planetary Policy: Embedding AI, ESG, and Media Art into Climate-responsive Governance

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Abstract

Cultural design is vital for addressing anthropocene challenges like climate change and technological shifts. This paper argues for embedding cultural design – encompassing media art, digital aesthetics, and participatory design – into policy and governance. This paradigm shift positions culture as strategic infrastructure, fostering emotional and systemic intelligence in decision-making. The paper explores three channels: AI-powered media art for planetary awareness, ESG-based cultural diplomacy (Jeju Island), and civic prototyping via public design (Seoul). Case studies from South Korea illustrate how creative governance drives climate-responsive and socially inclusive outcomes. This approach elevates design's role from aesthetic to strategic, advocating for its formal integration into global ESG and AI governance frameworks to align policies with planetary and human needs.

Keywords: Artificial intelligence, cultural design, ESG, governance, planetary policy.

Introduction

Design has emerged as a critical language of governance in the Anthropocene, an epoch defined by humanity's pervasive impact on Earth's systems. Traditional policy frameworks are proving insufficient to address complex planetary challenges like climate change, social inequality, and rapid technological change. This paper argues for a paradigm shift that embeds cultural design, encompassing media art, digital aesthetics, and participatory design, into the very fabric of policy and governance. By doing so, we can create more emotionally intelligent, resilient, and equitable systems capable of guiding humanity through the climate and AI transitions.

Cultural design is positioned here as a form of "planetary policy," meaning it treats culture not just as a soft power or afterthought, but as a strategic infrastructure for governance. This approach draws on environmental ethics, social innovation, and digital creativity to align human activities with the planet's boundaries. It recognizes that aesthetic and cultural dimensions are deeply entangled with ecological and social systems. In practical terms, cultural design as policy involves integrating artistic intelligence and design thinking into legislative processes, urban planning, and public engagement strategies. The goal is to foster emotional intelligence (through art and narrative) and systemic intelligence (through data and AI) in governance, enabling more holistic decision-making.

This work focuses on three channels through which this integration can occur:

1. **AI-powered media art in public spaces**: to build emotional infrastructure and raise planetary awareness.
2. **ESG-based cultural diplomacy**: using cultural assets as testbeds for sustainable development (exemplified by Jeju Island's initiatives).
3. **Civic prototyping via public design**: deploying design interventions as policy experiments (exemplified by Seoul's public design projects).

These channels are explored in detail, drawing on case studies from South Korea. South Korea provides fertile ground for such innovation: it is a country balancing rich cultural heritage with cutting-edge technology, and its cities and regions have increasingly adopted design-centric governance models. Through analysis of these cases – including AI media art installations, Jeju's sustainability initiatives, and Seoul's public design prototypes – the author illustrates how creative governance can drive climate-responsive and socially inclusive outcomes. We then discuss the broader implications of these shifts for global governance, proposing that design's role must evolve from the aesthetic to the strategic. Finally, we conclude with a call to formalize design as a foundational element of ESG and AI governance frameworks worldwide, to better align policy with planetary and human needs.

AI Media Art in Public Spaces: Emotional Infrastructure for Planetary Awareness

Public art has long been recognized as a catalyst for civic engagement, capable of transcending aesthetic appreciation to become a tool for social cohesion and critical reflection. In the era of climate urgency, AI-powered media art offers a powerful medium to foster emotional connections to environmental issues and future scenarios. By transforming public spaces into immersive galleries of data-driven art, cities can create an 'emotional infrastructure' that makes abstract planetary problems tangible and relatable.

Case in Point: Large Nature Model *Coral* at UN Headquarters

A recent example of this approach is the large nature model *Coral*, an AI-generated art installation unveiled at the United Nations in 2024. This monumental digital artwork, created by media artist Refik Anadol, uses a machine learning algorithm trained on 100 million images of coral reefs to project ever-shifting abstract visuals of these endangered ecosystems onto a 20 metre wall. The effect is mesmerizing, visitors are greeted by flowing shapes in green, orange, and white, accompanied by ambient music, evoking the beauty and fragility of coral reefs. Crucially, the piece is not just an aesthetic spectacle; it is a deliberate call to action. The installation was timed to coincide with the UN's high-level meetings on climate change and the Summit of the Future, subtly drawing attention to the climate crisis and the role of technology in addressing it. By visualizing the vast complexity of coral reefs – ecosystems that support 25% of marine life but are vanishing due to warming oceans – the artwork serves as a poignant reminder of what is at stake. As UN Under Secretary General Melissa Fleming observed, the piece is "a testament to the beauty and fragility of our natural world" and a "clarion call to world leaders" to harness technology and human ingenuity to protect the planet. This example illustrates how AI-driven media art can function as a form of soft governance: it influences perspectives, fosters empathy, and communicates scientific realities in a way that engages the senses and sparks dialogue.

Case in Point: *City Ascendant* in Los Angeles

Another illustrative project is *City Ascendant: Imagining the Future of L.A. through A.I.*, an art installation created by the USC Wrigley Institute in 2024. This exhibit features a series of dream-like scenes of Los Angeles transformed by sustainability – for instance, solar panels installed beneath the Hollywood Sign, container ships repurposed into lush ecosystems, and car-free streets filled with people and plants. Unlike apocalyptic climate imagery that can induce despair, these AI-generated visions present a hopeful narrative of urban sustainability. The curator's intent was to "encourage viewers to conceive a thriving future" achievable through immediate sustainability-centred changes. By departing from doom-and-gloom narratives, the project aims to inspire optimism and agency. This is grounded in research showing that relentless negative climate messaging can lead people to shut down, whereas hopeful visions can motivate constructive action. City Ascendant demonstrates how AI art can be a platform for envisioning positive futures, thereby contributing to climate communication strategies that prioritize hope and empowerment. The following chart visualizes the key differences between traditional climate communication and the more hopeful approach used in projects like *City Ascendant*.

Both of these cases highlight the potential of AI media art as a policy tool: it can make complex data (from climate science to urban systems) accessible and emotionally resonant. By embedding such installations in public institutions, be it a UN conference hall, a city museum, or a town square, policymakers can cultivate public awareness and support for sustainability measures. The immersive, multisensory nature of these works draws people in and encourages reflection. In effect, they become part of the emotional infrastructure of a city or community, subtly shaping attitudes and values. This emotional dimension is critical for climate action, as rational appeals alone are often insufficient to spur the necessary urgency and solidarity. Art engages the heart as well as the mind, helping to build the social will be needed for transformative change.

However, the deployment of AI in public art also raises important ethical considerations. Issues of data privacy, algorithmic bias, and cultural sensitivity must be carefully managed. For example, an AI art piece might use facial recognition or collect user data for interactivity, raising concerns about surveillance and consent. The creators of such works have a responsibility to ensure transparency about the data used and the algorithms employed. There are also questions of representation: if an AI artwork is meant to reflect a community, does it

do so in an inclusive, culturally respectful way, or might it inadvertently reinforce stereotypes? These are new frontiers for public art curation. In response, some artists and institutions are developing guidelines for ethical AI art, emphasizing principles like transparency, consent, and accountability. In practice, this could mean providing information panels about how an AI piece was made and what data it drew on or involving community members in the co-creation of AI-generated content so that it truly reflects their stories and values. By addressing these ethical challenges, AI media art can be deployed in a way that is empowering and equitable, rather than alienating or manipulative.

Despite these challenges, the trend is clear: AI-powered art is increasingly recognized as a democratic design tool for visualizing future scenarios and engaging diverse audiences. It can serve as a bridge between science and the public, translating complex information into visceral experiences. In doing so, it helps build what some scholars call an "ecological imagination" – the capacity to envision and care for the broader systems of life on Earth. This is a vital component of climate-responsive governance, which must not only formulate policies but also inspire public participation and commitment. As the UN's Coral installation and LA's City Ascendant show, when media art is aligned with planetary themes and ethical practice, it becomes a form of cultural policy that educates, provokes, and unites. It creates a shared experience around urgent issues, fostering a sense of collective responsibility. In sum, AI media art in public spaces provides an emotional infrastructure that complements the technical infrastructure of climate governance, making it more human-centred and effective.

Jeju as a Cultural ESG Testbed: Designing Governance through Soft Power

On the other side of the world from the UN's New York headquarters lies Jeju Island, a South Korean province that has become a living laboratory for integrating culture, sustainability, and governance. Jeju is renowned for its unique natural landscapes, from volcanic craters and lava tubes to lush forests, as well as its distinct cultural heritage, including a matriarchal fishing tradition and indigenous shamanic practices. In recent years, Jeju has leveraged these assets in pursuit of ambitious sustainability goals, essentially turning itself into a cultural ESG testbed. The island's government and organizations have developed initiatives that blend environmental stewardship, social development, and good governance with cultural preservation and creative diplomacy.

Jeju's Green Growth and Carbon Neutrality Vision

Jeju has positioned itself as a leader in sustainable development, adopting a vision of 'green growth' that harmonizes economic progress with environmental protection. In 2008, Jeju was designated a Special Self-Governing Province, granting it greater autonomy to experiment with policies. It seized this opportunity by launching the Jeju Free International City (JFIC) project, a long-term plan to transform Jeju into a globally recognized hub for eco-tourism, renewable energy, and cultural exchange. A centrepiece of Jeju's strategy has been its commitment to carbon neutrality. In 2022, Jeju announced an audacious plan to achieve carbon neutrality by 2035, 15 years ahead of South Korea's national target of 2050. To reach this goal, Jeju has been aggressively investing in renewable energy, sustainable transportation, and nature-based solutions. For example, the island has installed extensive solar panel arrays (often in partnership with local farmers, as shown in Figure 2) and wind turbines, and it operates one of the world's largest smart grid demonstration projects to integrate these renewables into the energy system. It has also introduced electric buses and is phasing out gasoline-powered vehicles. Jeju's efforts have not gone unnoticed: the World Bank has highlighted Jeju as a model for climate resilience, creating e-learning modules to share its innovative strategies with other regions.

Figure 1: A diagram illustrating the core components of Jeju's approach, which integrates culture, environment, and economy under an ESG framework. Source: Synthesized from case study descriptions of Jeju's initiatives

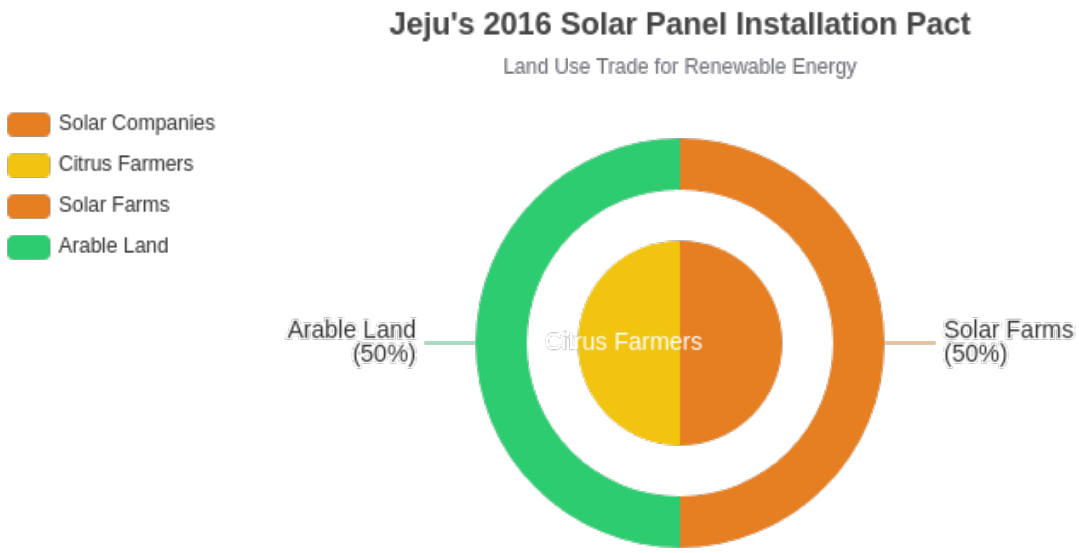

Figure 2: Jeju's solar panel installation data. Credit: Sociocultural Impacts of Renewable Energy: A Case Study on Jeju Island's Citrus Farmers

What makes Jeju's approach distinctive is the integration of culture into its sustainability agenda. Rather than treating culture as peripheral, Jeju uses cultural heritage as a foundation for sustainability and as a means of engaging global audiences. A prime example is the island's focus on eco-cultural tourism. Jeju's administration has promoted tourism experiences that showcase its natural beauty and traditions in an environmentally responsible way. Travelers can participate in guided hikes of UNESCO-listed sites, stay in traditional thatched-roof houses (hanok) that have been eco-renovated, or learn about the island's haenyeo female divers in an interpretive centre powered by solar energy. These initiatives not only preserve Jeju's culture but also educate visitors about sustainability. The income generated supports local communities, creating economic incentives for conservation. In this way, Jeju is demonstrating how cultural assets can be harnessed for regenerative economics, being economic activities that actively restore and sustain cultural and natural capital.

Another key aspect of Jeju's strategy is cultural diplomacy with an ESG lens. The island has played host to numerous international forums and events that combine culture, sustainability, and governance. Notably, Jeju has hosted the Jeju Forum for Peace and Prosperity, an annual gathering of global leaders, which often includes discussions on climate change and sustainable development. By providing a picturesque and culturally rich setting, Jeju leverages soft power to facilitate dialogue on hard issues. The island's unique status as a 'peace island' (it has a Peace Park and a history of reconciliation) adds a symbolic dimension to these meetings. Jeju officials have also established sister-city relationships and partnerships focused on sustainability. For instance, Jeju cooperates with other island communities worldwide to share best practices on renewable energy and waste management, often through cultural exchange programmes that include art exhibitions or environmental film festivals. These efforts position Jeju as a policy sandbox where new models of sustainable governance can be tested and showcased.

A concrete manifestation of Jeju's cultural ESG approach is the proposed K-Culture and ESG Foundation, which the author has been co-developing. This foundation envisions Jeju as a living museum and forum for sustainable culture. It would curate immersive experiences that highlight Korean cultural heritage through an ESG lens, for example, traditional craft workshops using eco-friendly materials, sustainable cuisine festivals featuring local organic produce, and AI art exhibitions that explore environmental themes. The foundation would also host an ESG Forum Series, bringing together policymakers, artists, and innovators from around the world to network and exchange ideas on integrating culture with sustainability. By attracting international visitors and thought leaders to Jeju, the foundation aims to turn the island into a global showcase of how culture can drive sustainable development. In essence, Jeju would become a soft power hub for sustainability, using its cultural appeal to advance its ESG goals and influence others to do the same.

Design is central to this endeavour, serving as both message and method. The design of physical spaces, such as eco-friendly cultural centres or renewable-energy-powered exhibition halls, sends a message about sustainable living. Likewise, the design of programmes and experiences (for example, a guided tour that is also a litter-pickup or a festival that offsets its carbon footprint) educates participants in an engaging way. Jeju's initiatives underscore the importance of place-based design: solutions are rooted in the local context (Jeju's geography, culture, and community needs) yet aligned with global sustainability frameworks. This ensures that development is culturally sensitive and locally supported, avoiding the pitfalls of one-size-fits-all sustainability models that may ignore cultural identity.

Early results from Jeju's experiments are promising. The island has seen improvements in environmental indicators (e.g. increased renewable energy generation, reductions in waste per capita) and has strengthened its cultural industries. Crucially, there is evidence of community buy-in, as locals see that their traditions and environment are valued and can be a source of pride and income. However, challenges remain. Balancing the influx of eco-tourists with the need to preserve fragile ecosystems is an ongoing concern. The island must also ensure that the benefits of its green economy are shared equitably among residents. Jeju's journey thus provides valuable lessons for other regions: it demonstrates how coupling cultural preservation with sustainability can create a virtuous cycle where culture motivates environmental action and a healthier environment in turn safeguards cultural heritage. Jeju's story is one of designing governance through soft power, showing that a region's cultural assets can be a strategic resource in the pursuit of ESG objectives. By branding itself as a sustainable cultural haven, Jeju has not only advanced its own development but also amplified its voice on the global stage, proving that cultural design can indeed function as planetary policy in action.

Policy Prototypes from the Ground Up: Seoul's Public Design Interventions

While Jeju showcases cultural design at a regional scale, the city of Seoul exemplifies its application in urban governance. Seoul, a metropolis of over 10 million people, has gained international attention for its innovative use of design to solve public problems and engage citizens. The Seoul Metropolitan Government (SMG) has institutionalized design thinking through initiatives like the Seoul Design Foundation and the Seoul Design Award, and it has even enshrined design in its legislative framework via the Seoul Public Design Promotion Ordinance. One of the most impactful approaches emerging from Seoul is the use of public design interventions as policy prototypes, essentially treating the city as a laboratory where temporary design projects test new ideas and gather feedback before they inform permanent policies.

Cheonggyecheon Stream Restoration

A landmark example of design-led governance in Seoul is the Cheonggyecheon Restoration Project, completed in 2005. In this project, the city removed an elevated highway that had buried the Cheonggyecheon stream and restored the waterway and surrounding public space. The restoration was not just an engineering feat, but a bold urban design intervention aimed at improving the city's environment and liveability. The result was a 5.8-kilometer long linear park flowing through the heart of Seoul, featuring tree-lined paths, waterfalls, and public art. The project had immediate positive impacts: it reduced ambient temperatures in the area by up to 5°C, improved air quality, and created a popular public amenity that sees millions of visitors annually. Economically, property values in neighbouring districts rose and the area became a hub for cultural and commercial activity. Importantly, Cheonggyecheon served as a prototype that influenced broader policy. It demonstrated the viability and benefits of prioritizing green infrastructure over concrete in dense urban areas. The success of this design intervention helped shift Seoul's urban planning paradigm towards more people-centric, sustainable development. Today, the principles from Cheonggyecheon (such as reclaiming urban rivers and creating green corridors) have been replicated in other Seoul projects and have informed the city's climate adaptation strategy (e.g., plans to cool the city and manage stormwater through nature-based solutions).

Public Design as Civic Prototyping

In recent years, Seoul has taken the idea of prototyping further by explicitly using temporary public installations and participatory design projects as policy experiments. The Seoul Design Foundation often collaborates with city departments to launch civic innovation design challenges, where designers, artists, and citizens co-create solutions to local issues. These interventions are deliberately short-term or pilot in nature, allowing the city to observe outcomes and gather public input before scaling up. One notable initiative is the Seoul Street Lab, a programme that invites proposals to reimagine small sections of the city's streets. For example, in one iteration, a busy roadway lane was temporarily converted into a pop-up park with seating, planters, and public art. This served as a test to see how people would use the space and what benefits (or issues) might arise. The positive response to such street interventions has directly informed Seoul's ongoing Slow Zone policy, which is gradually converting car-dominated streets into pedestrian-friendly zones in various neighbourhoods. By prototyping first, the city was able to build public support and fine-tune the designs (such as deciding optimal locations for parklets and ensuring accessibility) before implementing them permanently.

Another example is the use of media art and technology in public space as a policy probe. Seoul has installed interactive digital artworks in public squares and transit hubs that not only entertain and engage citizens but also collect data on public interaction. One such project was an AI-powered light installation in a downtown plaza that responded to people's movements and displayed real-time air quality data in creative visual forms. This installation was part research, part art: it gauged how citizens respond to seeing environmental data in a public setting and whether it prompts any behavioural changes or conversations. The insights from this prototype fed into Seoul's plans to incorporate more environmental data displays in the city (for instance, on digital billboards or smart street furniture) to raise awareness and encourage sustainable behaviours. It essentially tested the concept of using public space as an educational medium for climate action.

Seoul's public design process is highly participatory, often involving citizens in co-creation workshops. The city has recognized that when people feel a sense of ownership over a design, they are more likely to support and maintain it. Thus, many public design interventions begin with open forums where residents voice their needs and ideas. Designers then develop prototypes in consultation with the community. This bottom-up approach to policy ensures that solutions are grounded in real community priorities and are culturally attuned. It also serves as a form of public engagement that strengthens democracy – citizens are not just recipients of policy, but active contributors to its creation. The Seoul Metropolitan Government has documented these processes and outcomes in reports and even a Seoul Public Design Guidebook, sharing how design can be used as a governance tool for social problem-solving.

One flagship programme encapsulating these efforts is the Seoul Design Award, which, unlike traditional design awards that honour products, focuses on projects that improve daily life and solve urban issues. Winners of the Seoul Design Award often receive funding to implement their ideas in the city. For example, a winning proposal for an innovative way to recycle food waste was prototyped in a few neighbourhoods, and based on its success, the city expanded the programme citywide as part of its waste management policy. This demonstrates a direct pipeline from creative concept to public policy, facilitated by design.

Outcomes and Reflections

The impact of Seoul's public design interventions is evident in both tangible and intangible ways. Tangibly, the city has more green spaces, safer streets, and improved public facilities that emerged from these experiments. Intangibly, there is a growing culture of innovation and civic engagement. Residents have become accustomed to seeing their city as a work-in-progress that they can influence. This has led to a more resilient governance model – one that is adaptive and responsive. By prototyping policies in the form of design interventions, Seoul can quickly learn and iterate, which is crucial in a fast-changing world. It's a model of agile governance, where pilot projects serve as real-world tests, reducing the risk of large-scale policy failures and building public trust through transparency and inclusion.

However, implementing design as policy is not without challenges. It requires buy-in from various stakeholders, including city officials, bureaucrats, and the public. There can be resistance to temporary or experimental changes in a city that is used to more permanent planning. Additionally, measuring the success of such interventions can be complex. How do you quantify increased community cohesion or improved well-being from a public art project? Seoul has tackled this by using a mix of quantitative data (visitor counts, survey feedback, environmental metrics) and qualitative assessments (community testimonials, media coverage) to evaluate each prototype. This holistic evaluation then informs decisions on whether to scale up, modify, or phase out an initiative.

In summary, Seoul's experience illustrates that public design interventions can function as policy prototypes, effectively translating creative ideas into governance actions. They provide a bridge between the visionary ideas of designers and the practical realities of city life. By embedding these prototypes in the policy process, Seoul has made design an integral part of its governance toolkit, leading to more human-centred and innovative policies. The Seoul case offers a replicable model for other cities: by treating urban space as a canvas

for social innovation and involving citizens as co-designers, cities can address pressing issues (from climate adaptation to social inclusion) in a more creative and democratic manner. It's a powerful demonstration that design, when strategically applied, is not just about aesthetics – it can drive meaningful policy change from the ground up.

Discussion: Toward a New Role for Design in Global Governance

The cases of AI media art, Jeju's cultural ESG initiatives, and Seoul's public design prototypes each illustrate a facet of how cultural design can enhance governance. Collectively, they point toward a broader reimagining of design's role in shaping policy and society. In this discussion, we distill three key shifts that underscore design's evolving role in governance: shifts from object-focused thinking to systemic thinking, from expression to regulation, and from local impact to planetary alignment. These shifts are summarized in the figure below.

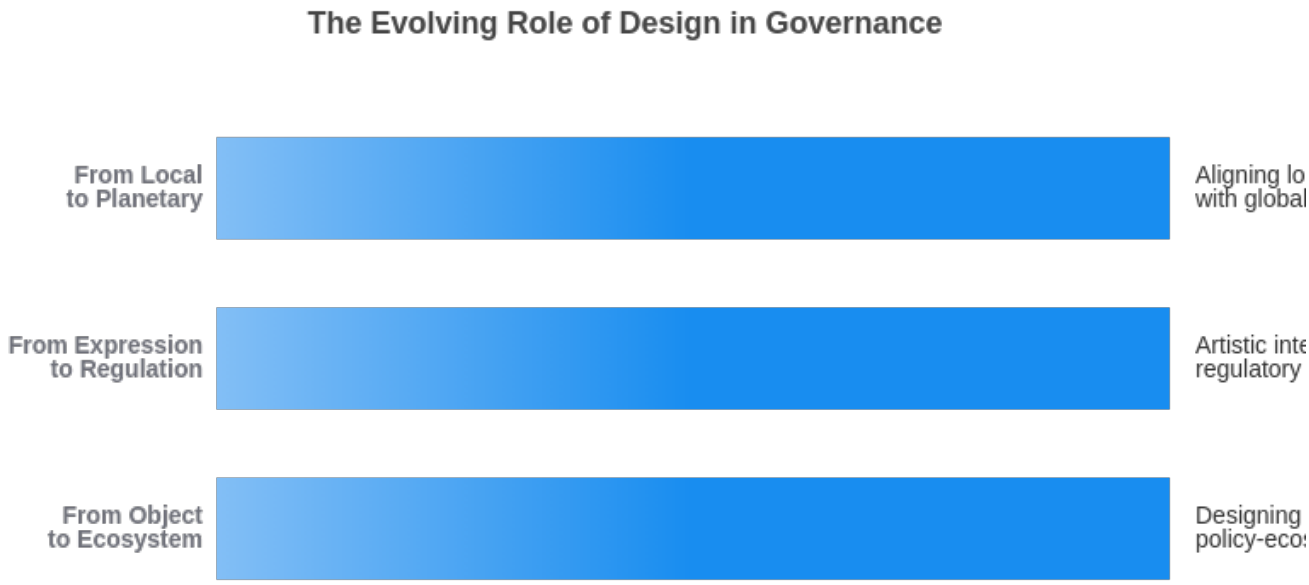

Figure 2: The three key shifts that underscore design's evolving role in governance.

From Object to Ecosystem: Designing Interconnected Policy-ecosystems

Traditionally, design has often been associated with creating individual objects or discrete projects: a building, a product or public artwork. While these are important, the planetary challenges we face demand a shift in scale and scope. The first pivotal shift is from designing isolated objects to designing interconnected ecosystems. In practice, this means that when we design a policy or intervention today, we must consider it as part of a larger system – social, environmental, economic, and cultural – and ensure it contributes to the health and coherence of that system as a whole.

This shift is evident in the examples above. Jeju's cultural ESG initiatives, for instance, are not one-off projects but part of an integrated strategy. The island's leadership recognized that sustainable development is not just about building green infrastructure or attracting tourists; it's about cultivating a holistic ecosystem where economy, society, and environment thrive in tandem. The proposed K-Culture and ESG Foundation on Jeju exemplifies this systems approach: it does not focus solely on environmental goals or cultural goals in isolation but seeks to merge them so that cultural programmes support environmental objectives and vice versa. By doing so, Jeju is effectively designing a new kind of policy ecosystem – one that is regenerative and resilient.

Similarly, Seoul's public design interventions, while often localized, are conceived within the context of the city's overall development plan and climate strategy. A temporary park on a street is not just about that one street; it's part of a network of green interventions aimed at making the entire city more liveable and climate-resilient. The city treats each project as a node in an ecosystem of initiatives, learning lessons that inform other projects. This systemic perspective ensures that individual design interventions reinforce each other rather than work at cross-purposes.

Designing ecosystems also implies adopting a transdisciplinary approach. No single discipline has all the answers to complex problems like climate change. Designers must collaborate with scientists, policymakers, community members, technologists, and artists to create solutions that are comprehensive. The AI media art projects discussed earlier are a case in point as they required collaboration between artists, data scientists, engineers, and often subject-matter experts (like marine biologists for a coral reef project). By breaking down silos, these projects achieved outcomes that were greater than the sum of their parts. The ecosystem approach in design governance means building cross-sector partnerships and fostering networks of stakeholders. In Jeju's case, partnerships between the local government, private enterprises, NGOs, and academia have been crucial to its green transition. In Seoul, co-creation with citizens and community groups has been a cornerstone of design projects.

Moreover, measuring success shifts from counting outputs (e.g., number of artworks installed or tourists attracted) to assessing systemic outcomes (e.g. improvement in community well-being, reduction in carbon emissions, enhancement of cultural vitality). This aligns with frameworks like the United Nations Sustainable Development Goals (SDGs), which emphasize the interconnectedness of goals such as climate action, sustainable cities, and cultural preservation. Designing for an ecosystem means aiming for win-win-win solutions that advance multiple objectives simultaneously. For example, a well-designed urban park can improve public health,

manage stormwater, sequester carbon, and provide cultural gathering spaces, hitting environmental, social, and economic targets all at once. This kind of integrated impact is the hallmark of ecosystemic design.

In summary, the shift from object to ecosystem in design governance calls for thinking in terms of networks, relationships, and feedback loops. It encourages resilience, because an ecosystem approach builds redundancy and flexibility – if one component fails or changes, the whole system can adapt. It also fosters sustainability, as interventions are crafted to fit into the larger web of life rather than exploit or disrupt it. As we design policy-ecosystems, we move closer to the ideal of planetary design, where human systems are consciously aligned with the Earth's systems for mutual benefit.

From Expression to Regulation: Artistic Intelligence as a Regulatory Tool

The second significant shift is the recognition that artistic intelligence and design thinking can inform and even function as forms of regulation and governance. Traditionally, art and policy have been seen as separate realms: art as self-expression or cultural enrichment, and policy as formal rules and regulations. However, the cases we explored show a convergence where art and design are being strategically used to shape behaviour, norms, and even formal rules in society.

Art has always had an implicit regulatory effect on society by influencing norms and values. For instance, literature, film, and visual art have shaped public opinion on issues from civil rights to environmental conservation. What's new in the current context is the deliberate, proactive integration of artistic and design methods into the process of governance. In other words, policymakers are increasingly asking: how can we use art, design, and creative media to communicate policy, build public support, and even achieve policy outcomes more effectively?

The AI media art installations discussed earlier are a prime example. They are not just random expressions, they are carefully curated to convey specific messages (about climate urgency, about future possibilities) and to elicit specific responses (contemplation, hope, concern) from the public. In this sense, they function as a form of soft regulation or norm entrepreneurship. They don't enforce laws, but they shape the cultural environment in which laws and policies are received. By fostering empathy for nature or inspiring sustainable lifestyles, these artworks create a social context more receptive to strict environmental regulations or personal sacrifices for the common good. As noted, the UN's coral reef AI artwork was a clarion call to world leaders, indirectly pushing them towards stronger climate action through the power of imagery and emotion. This is a subtle but powerful way that art can influence the policy process.

Design thinking, too, is being used to improve the design of regulations and public services. Governments around the world are setting up design labs and hiring design experts to reimagine how policies are formulated and delivered. The core idea is that by applying user-centred design principles, policies can become more effective and equitable. For example, instead of drafting a new urban policy in an ivory tower, designers might conduct ethnographic research in neighbourhoods, prototype pilot programmes, and iteratively refine the policy based on feedback – much like a product designer would refine a product. This approach leads to regulations and services that are more attuned to people's needs and thus more likely to be followed and supported. It transforms policy from a top-down dictate into a co-created solution.

Another dimension of this shift is the use of participatory design and art as a regulatory mechanism. In community planning, for instance, collaborative design workshops can lead to agreements and norms that residents voluntarily adhere to, reducing the need for heavy-handed enforcement. A neighbourhood that collectively designs its public space is more likely to take care of that space and self-regulate behaviours (like keeping it clean or resolving conflicts) because they feel ownership. This has been observed in Seoul's public design projects and other participatory governance experiments globally. By engaging citizens in creative problem-solving, authorities tap into a form of self-regulation and social control that is more organic and sustainable than external rules.

There is also a growing movement to incorporate artistic and cultural indicators into policy evaluation. Traditionally, policymakers might measure success in economic or technical terms. Now, some are recognizing that metrics of cultural vibrancy, public happiness, or social cohesion are equally important for well-being. For example, a city might assess a new urban policy not just by traffic flow or cost savings, but by whether it has fostered a sense of community or inspired local art and culture. This broader evaluation encourages policies that are not just efficient but also meaningful and humanizing. It's important to note that this shift does not mean replacing formal regulation with art. Rather, it's about integrating the two so that hard policies are complemented by soft cultural strategies. A law banning single-use plastics, for instance, will be more effective if accompanied by a creative public awareness campaign that makes reusable alternatives socially desirable. In this way, artistic intelligence amplifies the impact of regulatory intelligence. They work hand in hand to change both behaviour and mindset.

One could argue we are seeing the emergence of aesthetic governance: governance that is attuned to aesthetics, narratives, and cultural context. Cities like Seoul explicitly use the term 'public design' in their ordinances to mean not just the look of things, but the way public problems are solved. This indicates a recognition that good design (in the broad sense) leads to better governance. It's a shift from seeing art and design as decorative add-ons to understanding them as instruments of governance that can shape attitudes, build consensus, and even prevent problems by designing them out (for example, designing public spaces that discourage crime or designing apps that nudge users towards energy savings).

In conclusion, the shift from expression to regulation in design's role means that creative practices are being woven into the fabric of how we govern. Art and design are no longer outside the policy process commenting on it; they are inside it, helping to craft it. This can lead to policies that are more humane, imaginative, and effective, because they engage people's hearts and minds, not just their compliance. It also makes governance more resilient, as cultural approaches can adapt and evolve more quickly than laws, helping societies navigate change with agility and grace.

From Local to Planetary: Aligning Local Design with Global Governance

The third shift is about scale: moving from thinking locally to thinking globally and ensuring that local design interventions align with and contribute to global governance frameworks. In an interconnected world, local actions have global repercussions and vice versa. Climate change is the most obvious example: a city's emissions or a country's policies can affect the entire planet. Conversely, global agreements like the Paris Climate Accord or the UN SDGs must be translated into local actions to be realized. Cultural design can play a pivotal role in this translation process, acting as a bridge between the universal and the particular.

One aspect of this shift is the recognition that local cultural contexts are crucial for global solutions. Global challenges like climate change cannot be solved with uniform, one-size-fits-all solutions imposed from the top. They require adaptation to local cultures, economies, and geographies. Cultural design emphasizes the importance of place and context – it asks: What is the unique contribution or perspective of this community to the global problem? By honouring local knowledge and culture, global governance can become more inclusive and effective. For instance, Indigenous communities around the world possess deep ecological knowledge and sustainable practices honed over generations. Integrating these into global climate strategies (through cultural design initiatives, storytelling, and participatory processes) can enrich our collective response to climate change. It ensures that global frameworks like the SDGs are not just abstract goals but resonate with lived realities and values.

Jeju Island's approach again provides an instructive example. Jeju is a local context with a very specific identity, yet its initiatives are explicitly aligned with global sustainability goals. The island's push for carbon neutrality by 2035 aligns with the Paris Agreement's objectives and demonstrates how a sub-national entity can take ambitious action to support global climate targets. Moreover, Jeju actively shares its experiences internationally, effectively contributing to global knowledge exchange on sustainable tourism and renewable energy. Through forums and partnerships, Jeju's local innovations feed into the global discourse, potentially inspiring other regions. This illustrates a virtuous cycle: local success strengthens global frameworks, and global frameworks provide legitimacy and additional resources for local action.

Cultural design also helps in communicating global issues in local terms. Climate change, for example, is often communicated through global statistics and abstract concepts. But people connect more strongly with local manifestations – a familiar landscape affected, a local tradition impacted by changing weather. By using local cultural expressions (stories, art, symbols) to talk about global issues, we make those issues more tangible and urgent to local communities. An AI art installation about coral reefs might be globally minded, but if it's placed in a local aquarium or community centre and perhaps incorporates local marine species, it becomes a story about our ocean, our planet. This localization of global narratives is a key function of cultural design in governance. It ensures that global policies (like carbon reduction targets or biodiversity conservation plans) are not perceived as distant mandates, but as part of the community's own story and aspirations.

Another important facet is the concept of planetary identity and solidarity. As we face global challenges, there is a need to foster a sense of shared identity as inhabitants of one planet – a planetary citizenship. Cultural design can contribute to building this identity by creating shared experiences and symbols that transcend local differences. For example, global art projects or events (like Earth Day art installations, or global art competitions on climate themes) can give people around the world a sense of participating in a common endeavour. The earlier mentioned UN coral reef installation is a case in point: it was displayed at a UN venue, bringing together people from all nations under one roof to contemplate a shared ecological treasure. Such experiences reinforce that we are all in this together, which is crucial for effective global governance (since cooperation is needed to solve global problems).

Local governments and cultural institutions are increasingly networking through platforms like the United Cities and Local Governments (UCLG) or the C40 Cities Climate Leadership Group to exchange ideas on sustainable urban design. This horizontal exchange is an important part of aligning local action with global goals. Cities share design solutions for issues like climate adaptation, and in doing so, they help standardize best practices while still allowing room for local customization. Cultural design often features in these exchanges – for instance, how different cities use public art to promote recycling or use traditional architecture techniques to build climate-resilient housing. These exchanges ensure that no city or region is reinventing the wheel alone and that innovations spread faster.

However, aligning local and global also requires policy coherence. National and international policies should support and not undermine local cultural design initiatives. There is a growing call for global governance frameworks to include cultural dimensions explicitly. UNESCO's recommendation on cultural policies for sustainable development is one such effort, urging countries to integrate culture into all aspects of development planning. Similarly, the concept of culture as the fourth pillar of sustainable development has gained traction, meaning culture should be on par with economic, social, and environmental considerations in policy. When this is recognized, local cultural design projects can receive the support (funding, institutional backing) needed to flourish and scale up.

In essence, the shift from local to planetary is about thinking globally and acting locally – but also feeding local learning back into global frameworks. Cultural design is a medium through which local communities can both implement global goals and influence their evolution. It ensures that global governance is not an abstract exercise at the top, but a living process that connects with the creativity and diversity of communities worldwide. By embedding design in climate adaptation, cultural memory, education, and digital literacy at all levels, we create a more robust and human-centric approach to planetary governance. Design becomes a common language that can translate complex global challenges into actionable, culturally resonant projects on the ground, while also translating the voices and wisdom of local communities back into the global decision-making arena.

Conclusion

The convergence of cultural design with governance offers a hopeful path forward in an era defined by climate upheaval and technological disruption. Through the cases and analysis presented, we see that design – when strategically applied – can be a potent force for positive transformation. It bridges the gap between hard policy and soft values, between scientific knowledge and public understanding, and between global imperatives and local action. In short, cultural design can be the thread that weaves together a more coherent and compassionate approach to planetary governance.

One of the key insights of this paper is that design must be embedded into the very DNA of governance if we are to achieve sustainable and equitable futures. This means formalizing the role of design in institutions and frameworks that guide our collective actions. For example, governments could establish chief design officers or design advisory boards to ensure that policy proposals are evaluated not only for their economic and technical feasibility, but also for their human-centredness, cultural appropriateness, and aesthetic impact. International organizations like the United Nations could integrate design thinking into their development programmes, recognizing that creative solutions are often as important as financial aid or technical fixes. By making design a formal part of ESG (Environmental, Social, Governance) criteria and AI governance frameworks, we send a clear signal that aesthetics, ethics, and human experience are core to how we measure success in the Anthropocene.

Embedding design in governance also implies investing in capacity building – educating policymakers and citizens in design thinking and fostering collaboration between the creative sector and public sector. Fortunately, we are already seeing movements in this direction. Design schools and public policy schools are increasingly collaborating, and there are fellowships that place designers in government agencies to work on real-world problems. Such initiatives help break down stereotypes and build a shared language between artists/designers and policymakers. Over time, this can lead to a culture within governance where innovation, creativity, and empathy are valued as highly as analytical rigor and compliance.

The cases from South Korea provide a roadmap that other regions can learn from and adapt. Seoul's journey shows the value of starting small – prototyping in neighbourhoods – and scaling up with evidence and public support. Jeju's example highlights the importance of aligning local identity with global goals, turning cultural pride into a driver for sustainability. The use of AI media art suggests new ways to engage the public's imagination and emotion in service of policy objectives. These are not isolated successes; they are part of a broader pattern of creative governance emerging worldwide, from Singapore's use of art in urban planning to European cities experimenting with tactical urbanism and community design charrettes.

Crucially, cultural design as planetary policy is not a panacea. It must work in tandem with strong regulatory measures, scientific innovation, and social justice initiatives. Design can help craft policies that people will embrace, but it cannot replace the need for equitable distribution of resources or enforcement of necessary rules. However, it can make those policies more effective by ensuring they are well-crafted and well-received. A policy that is beautifully designed (in both form and function) stands a far greater chance of success than one that is technically sound but culturally tone-deaf or communicated poorly.

Looking ahead, we can envision a future where every major policy decision undergoes a design review – much like an environmental impact assessment – to gauge its human and cultural dimensions. We can imagine cities where public spaces continuously evolve through community design input, remaining vibrant and responsive rather than static. We can imagine global summits where art installations and cultural performances are integral to the proceedings, not just side events, because they help crystallize the conference's message and build emotional commitment among participants. In essence, we can move toward a world where governance is not seen as a dry, bureaucratic process, but as a creative endeavour – one that draws on the full spectrum of human intelligence, including artistic, intuitive, and empathetic capacities.

In closing, Design for Planet is about designing beyond the object. It is about seeing governance itself as a creative act – the act of designing the systems in which we all live. By embracing cultural design as a planetary policy, we honour the fact that we are not only rational actors but also cultural beings, deeply moved by stories, symbols, and beauty. This holistic view of humanity can inform governance that is more integrative and wiser. The invitation extended in this paper is to all stakeholders, from designers to artists, policymakers and citizens, to recognize themselves as co-designers of our collective future. By working together across disciplines and scales, we can navigate the complexities of the Anthropocene with greater care, creativity, and hope. Design, in this sense, becomes not just a profession, but a responsibility and a practice for us all, as we strive to craft societies that are sustainable, just, and meaningful on a planetary scale.

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Design for Scotland: Towards a National Design Policy for a Creative, Equitable, and Climate-responsive Future

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Abstract

Design is increasingly recognized as a critical resource for addressing complex societal challenges, yet its potential remains underutilized within national policy frameworks. In Scotland, as elsewhere, there is growing momentum to move beyond viewing design solely as part of the creative industries, towards positioning it as a driver of economic resilience, social innovation, and systemic transformation. The *Design for Scotland* initiative, led by V&A Dundee and supported by Creative Scotland, responds to this opportunity by advocating for a national design policy vision that is inclusive, imaginative, and aligned with urgent priorities. This paper builds on the first phase of independent research led by GRAFT, Studio AndThen, and How2Glu, which established the conceptual and methodological foundations for advocating the broader value of design. We are now entering a second phase, which aims to bring this vision to life through V&A Dundee's status as a national museum mobilizing design-led research, advocating for both a national design policy and the integration of design in policymaking, and enabling the cultural activation of these ideas at scale. This paper sets out a vision for the future of design policy conversations in Scotland, positioning design as a strategic tool for governance, well-being, and systemic innovation, while offering a transferable model internationally.

Keywords: Climate resilience, design policy, participatory design, speculative design.

Introduction

Design for Scotland: Design for... is a national initiative developed to address broader systemic issues aligned with 21st-century design challenges. Building on earlier iterations of a *Design Project for Scotland* and a series of initiatives over recent decades, the work responds to long-standing efforts by Scotland's design sector to champion the value of design to government and society. In 2022, with funding from Creative Scotland**,** V&A Dundee launched *Design for Scotland* to take this ambition further.

At its core, *Design for Scotland* seeks to demonstrate how design can help address the defining challenges of our times whilst recognizing the intrinsic links between the health of people and the planet, from how we deliver healthcare and the clothing we consume and use, to the food we source and grow, and the educational models that shape our children. Through the evolving *Design for...* banner, this programme aims provides a unifying framework to explore design's role across these diverse contexts, whether it be *Design for Farming*, *Design for Play* or *Design for Fashion* to name a potential few. Each iteration will ask how design can advance equity, well-being, and climate resilience through creative, collaborative, and place-based approaches.

Scotland's art and design schools are central to this vision, producing graduates who not only power the creative industries but also drive innovation across every part of the economy. Today, around 40% of Scotland's largest companies, charities, and public bodies have in-house design teams (GRAFT et al 2024), evidence that design is already a quiet but powerful force in how the nation lives, works, and imagines its future.

Design and 21st Century Challenges

Globally, design is increasingly recognized as having value far beyond aesthetics. Design thinking now shapes boardroom strategy (Brown 2009; Friedman 2003; Frayling 1993); service design is transforming healthcare systems (Patrício et al. 2020); transformation and systems design are reimagining how organizations and societies function (Irwin 2015; Lockton et al. 2019); and design for policy is gaining momentum across the world (Bason 2016; OECD 2018). At V&A Dundee, our position is deliberately broad: we advocate for design in all its forms. But to convene, curate, and coalesce this potential, Scotland needs a national design policy.

Design is a vital asset in tackling the great challenges of our time. Yet within national policy frameworks, its potential remains underused (Whicher 2021). In Scotland, as in many parts of the world, momentum is growing to formalize design's role not only as part of the creative industries, but as a catalyst for economic resilience, social innovation, and systemic transformation (Cooper 2025; Kimbel et al. 2025).

A quarter of the way into the 21st century, societies are navigating overlapping social, economic, environmental, and democratic pressures (Mulgan 2019). In Scotland, this means accelerating the transition to a net-zero economy; fostering innovation; advancing wellbeing and fair work; tackling inequality; strengthening communities; and redesigning public services to meet rising demand with limited resources. In short: there has never been a greater need for design.

History shows that in moments of disruption, design has been deliberately harnessed for national renewal. The UK's Design Council was created in 1944 to aid post-war recovery by improving industrial design (Woodham 1995). A century earlier, the Schools of Design including the Glasgow School of Art were established to strengthen Britain's competitiveness (Harrod 1999). The Victoria and Albert Museum (V&A) itself was born from the same conviction, founded after the Great Exhibition of 1851 as a national design resource with a mission that was as economic as it was cultural (Weddell 2018; Burton 1999).

That legacy is instructive today. Recognized as a systemic tool, design enables governments, businesses, and communities to embed creative, human-centred, and evidence-led approaches into policy, services, and infrastructure (Kimbell 2011; Manzini 2015). At its best, design policy is not about serving the design sector in isolation. It is about unlocking design's multiplier effect across national life fuelling growth, strengthening cohesion, and enabling nations to adapt with agility to challenges that defy simple solutions.

International Examples

Embedding design within a national strategy is inherently complex. It requires time to build awareness, shift organizational cultures, and create the structures that enable design to flourish within policymaking. In Scotland, this ambition is being pursued through two complimentary routes. The first is advocacy making the case for design not only in terms of its economic contribution, but also for its wider impact on culture, well-being, and sustainability. The second is integration by embedding design approaches across policy areas so that creative, human-centred, and systemic thinking becomes part of the everyday machinery of government. This dual approach reflects what Mazzucato (2018) describes as *mission-oriented innovation*: aligning creativity, research, and public purpose to address complex societal challenges. Similarly, embedding design within governance requires both strategic vision and cultural transformation and a long-term commitment to using creativity not as decoration, but as a driver of structural and systemic change.

Internationally, there is now a diverse range of examples that illustrate different pathways toward embedding design in governance. Denmark's MindLab, under the leadership of Bason (2010), remains one of the most influential cases in Europe, demonstrating how design can reshape public services around citizens' needs. Sydney has established a Chief Design Officer, New York has mobilized both the Mayor's Office of Data Analytics and Bloomberg Philanthropies' innovation teams, and other contexts have turned to universities and student programmes to cultivate design capability for public value. These initiatives show that design can be institutionalized through many different means through leadership roles, philanthropic support, or education pipelines but all share the goal of using design as a lever for systemic change.

The UK provides further evidence of design's gradual but steady integration into policymaking. A growing community of practice now exists across government, with the UK Government Cabinet Office Policy Lab at its core (UK Government 2021). Through prototyping, co-creation, and visualization, the Lab has demonstrated how design methods can bring experimentation into policy development and place citizens' perspectives at the centre of decision-making (Kimbell et al. 2025). In Scotland, this movement is reinforced institutionally through the Office of the Chief Architect and the Office of the Chief Designer, with service design now embedded in civil servant onboarding as part of a broader cultural shift within government (Scottish Government

2018). Glasgow City Council – Scotland's largest local authority has established a Centre for Civic Innovation to put design at the heart of creative problem solving and training citizens to be co-designers (Centre for Civic Innovation 2025). These steps underline that design is no longer a peripheral skill but increasingly recognized as a capability essential to effective governance.

V&A Dundee plays a complementary role in this landscape as the UK's only national design museum outside London, part of the V&A family but rooted in founding values of supporting the creative industries and fostering design-led growth. Its presence signals the recognition of design not only as heritage and culture but also as infrastructure for innovation. In doing so, it positions Scotland to champion design's broader role across society curating, convening, and advocating for its value in ways that reach beyond government into industry and communities.

This trajectory aligns closely with Mazzucato's vision of the 'design economy,' where culture, creativity, and design are treated as central drivers of inclusive and sustainable prosperity (Mazzucato 2018; Design Council 2021). Taken together, these examples show that embedding design is not simply about declaring its value, but about creating the conditions through institutions, policy frameworks, and cultural advocacy for design to transform governance, industry, and society in enduring ways. V&A Dundee now aims to take this role forward as a key organization to influence and support the design economy, while championing, curating, and convening the partnerships needed to realize it.

The next sections outline how this ambition is being realized in practice first through Phase 1, which established the conceptual foundations for a national design vision, and then through Phase 2, which builds the framework and partnerships required to bring that vision to scale.

Phase 1: Building the Case for a National Design Vision

During Phase 1 (2023–2024), V&A Dundee commissioned independent research funded by Creative Scotland's National Lottery Fund, led by the design agencies GRAFT, in partnership with Studio AndThen and How2Glu. The research combined a comparative review of international design policy models, including examples from across Europe, with stakeholder interviews and a series of visioning workshops involving representatives from government, education, industry, and the civic sector. These participatory engagements identified key opportunities and barriers to embedding design within Scotland's policy architecture. The findings are summarized in an executive report and a series of six thematic briefing papers (GRAFT et al. 2024).

One of the clearest findings from Phase 1 was around the value of Scotland's design economy. Scotland's design sector is both substantial and highly productive. It contributes around £6.79 billion GVA annually and employees over 137 000 people, on par with the food and drink sector. Design generates 50% more GVA than tourism while employing 50% fewer people, underlining its productivity and innovation potential. Between 2017 and 2019, the sector grew by 33%, five times faster than the Scottish economy overall. The sector is also highly diverse, spanning architecture, advertising, fashion, digital, graphic, multimedia, and product design. Importantly, over 118 000 design roles are embedded in non-design sectors, and 40% of Scotland's largest companies, public bodies, and charities have in-house design teams, illustrating design's cross-sectoral reach.

This phase also compared Scotland with 13 international examples of design sector support across Europe, showing how other nations integrate design into research and development, public service innovation, and sustainability initiatives. In Scotland too, design was increasingly deployed in healthcare, education, and government services, where it has the potential to improve outcomes, foster inclusive governance, and advance climate resilience. Furthermore, a participatory approach underpinned the research. Interviews, a cross-sector working group, three future-visioning workshops, and an interactive online survey inviting respondents to act as Scotland's first Minister for Design generated rich data. The survey in particular revealed strong support for positioning design as a driver of social value, building a national design skills pipeline, stimulating demand through government-led investment, and developing a national design policy. Respondents also stressed the need to tackle barriers such as limited funding, closed procurement processes, and risks to sectoral diversity.

Image 1: *Design for Scotland* Phase 1 working group session. Credit: Studio AndThen

The participatory research identified a lack of a shared language or narrative around our collective definition of design and that communicates the public value of design across sectors. Rather than treating design solely as a commercial or aesthetic concern, the project reframes it as a method of inquiry and innovation capable of advancing systemic change (Manzini 2015).

Recommendations from Phase 1:

1. **Embed design at the heart of national strategy**: position design as a central pillar of Scotland's national strategy to unlock its full creative capacity, strengthen leadership, foster innovation, and deliver long-term social and economic benefits.
2. **Establish a national *Design for Scotland* programme**: develop a unifying national framework that demonstrates the impact of design across sectors, supports strategic projects, and builds public and institutional understanding of design's value.
3. **Invest in education, skills, and talent retention**: address long-standing gaps in design education and professional development by working with partners across higher and further education, funding bodies, and employers to shape future design capacity and retain talent within Scotland.
4. **Foster collaboration and partnerships**: convene stakeholders from across industry, academia, and the public sector to create a coordinated approach to design-led innovation, ensuring alignment between policy, funding, and practice.
5. **Develop a robust measurement and evaluation framework**: establish baseline data on design awareness, application, and impact, and create a continuous feedback loop to inform future strategy, policy, and investment decisions.
6. **Build supportive policy and investment frameworks**: integrate design into wider government agendas social, economic, democratic, and environmental to ensure coherent support and sustained investment in the sector's growth.

Together, these recommendations provide the foundation for a national design strategy that positions Scotland as an international leader in harnessing design for societal transformation. By investing in skills, collaboration, and evidence-based policy, Scotland can ensure that design not only thrives as a sector but also becomes a powerful driver of national progress.

Phase 2: From Insight to Implementation

Phase 2 marks a critical transition from research to implementation, to turning insights into action, and evidence into policy. Building on the foundations established in Phase 1, this stage operationalizes the Design for Scotland vision through targeted programmes, partnerships, and evaluation. Its purpose is to move beyond advocacy to embed design as a central mechanism for innovation and governance within Scotland's policy landscape.

Guided by three interrelated aims (1) to advocate for a national design policy that formalizes design's strategic role, (2) to elevate design as a tool for policy development and societal transformation, and (3) to support and strengthen Scotland's design economy. Phase 2 focuses on implementation through collaborative and measurable action.

Image 2: Design for Scotland partners Ilka, GRAFT, Centre for Civic Innovation and V&A Dundee at V&A Scottish Parliament Reception. Credit: Grant Anderson (left) and Kyle Taylor (right)

Phase 2 Plan:

1. ***Design for Scotland: Design for...* – titled national events programme**: this series of seminars, workshops, and public events will explore the transformative potential of design across sectors – Design for Scotland – Design for... representing through themes such as farming, fashion and play. Anchored in speculative and participatory design methods, the events aim to inspire new models of civic infrastructure and participatory public programming. International contributors and case studies will offer global context while showcasing Scotland's distinct design capabilities.
1. **Design Policy Labs and stakeholder co-creation**: three national Design Policy Labs will convene diverse stakeholders, public officials, educators, entrepreneurs, and civil society leaders to co-develop a roadmap for a Scottish design policy. Using design principles, these labs will explore long-term, place-based strategies for embedding design in policy development and delivery. Outputs will include actionable frameworks and shared visions for design-enabled systems change.
2. **Strategic communications and cultural activation**: recognizing the importance of public engagement and visibility, the project includes a cultural communications strategy led by the design agency Ilka. This includes the development of a public-facing visual identity, infographics, exhibition materials, and storytelling tools that translate research insights into accessible narratives. The aim is to shift public perception and institutional understanding of design's relevance in shaping equitable and resilient futures.

Future Minister: From Speculative Manifesto to Policy Lab

During Phase 1, a speculative design exercise invited participants to imagine themselves as Scotland's first Minister for Design, using design fiction and provocation to surface priorities for a future national strategy. This imaginative exercise proved to be a powerful tool for engagement, generating qualitative insights and revealing a strong public appetite for systemic change in how design is valued and governed.

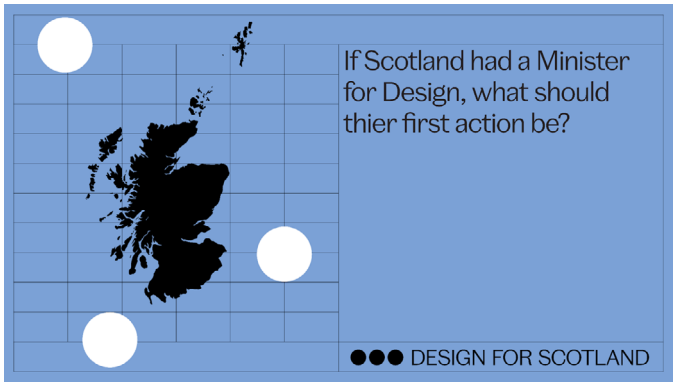

Image 3: Speculative Design Activity of a Fictional Minister of Design for Scotland. Credit: V&A Dundee

In Phase 2, this approach will be scaled up into a national Fictional Minister for Design survey, running throughout 2026. The expanded initiative will serve as a participatory platform for gathering diverse perspectives on the future role of design in Scotland's society, economy, and governance. Insights from the survey will inform the establishment of the Design for Scotland Policy Lab, based in the V&A Dundee Residency Studio. The Lab will embed design-led experimentation within the museum's national role, hosting residencies, workshops, and collaborative research that bring together policymakers, academics, and practitioners to explore how design can shape public policy and systemic innovation.

In parallel, a national interactive online survey grounded in speculative design will capture shifts in attitudes, capabilities, and opportunities across Scotland's design ecosystem. By generating longitudinal data, it will help define how design engages with policy and it will inform the ongoing development of the *Design for...* programme.

By situating design within national strategic priorities and linking creative practice to civic outcomes, *Design for Scotland: Design for...* aims to create a participatory space for policy co-creation and public dialogue. The Policy Lab will function not only as a site of live design research but as a vital piece of cultural infrastructure testing how design methods can inform governance, stimulate innovation, and generate inclusive, evidence-based solutions to Scotland's most pressing 21st-century challenges.

Conclusion and Next Steps

In the face of 21st-century challenges – climate change, widening inequality, demographic shifts, and rapid technological disruption, Design for Scotland has never been more vital. As systems of governance, care, and economy undergo profound transformation, design offers a means of connecting creativity with public purpose. It enables Scotland to reimagine how national priorities are shaped, fostering collaboration and crafting policies that are both imaginative and evidence based.

At its core, *Design for Scotland* seeks to formalize design's strategic role within national decision-making, elevate it as a tool for policy development and societal transformation, and strengthen the resilience and visibility of Scotland's design economy. These aims underpin a long-term effort to demonstrate that design is not only an economic asset but also a civic and strategic resource essential to the wellbeing of people and planet.

Phase 2 marks a pivotal stage in realizing this vision. Building on the foundations of Phase 1, which mapped the policy landscape and identified opportunities for national coordination, the next phase will deepen the evidence base through a comprehensive analysis of Scotland's design economy. Working collaboratively with stakeholders, the project will co-design a Theory of Change model to articulate how design contributes to economic, social, and environmental outcomes. The establishment of Design Policy Labs at the V&A Dundee residency studio will translate these insights into tangible prototypes of policy in action spaces where design methods are used to test, communicate, and influence real policy processes. Running alongside this, the Fictional Minister for Design survey in 2026 will invite policymakers and the public alike to imagine new futures for design within governance.
Looking ahead, Phase 3 will evolve the *Design for...* banner into a long-term framework for design-led policy and public engagement. Thematic strands such as *Design for Farming*, *Design for Play*, and *Design for Fashion* will illustrate how design can drive regenerative practice, reimagine learning, and promote equity and climate justice.

Anchored in the V&A's founding ethos that design underpins both cultural enrichment and industrial progress, this work positions design as public infrastructure for a fairer, greener, and more resilient Scotland. In alignment with Mazzucato's (2018) mission-oriented innovation framework, *Design for Scotland* demonstrates how creativity and public purpose can converge to deliver systemic change. Ultimately, it envisions a future where design functions not merely as an aesthetic or economic driver, but as a strategic civic resource connecting people, policy, and place. Most importantly, this is a live design research programme in progress and as the work develops, the team continues to learn from other countries, partners, and disciplines, sharing insights openly to foster dialogue and mutual learning across borders. In this spirit, Design for Scotland remains both an experiment and an invitation and a collective effort to explore how design can connect people, policy, and place to shape inclusive and sustainable futures for Scotland and beyond.

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Designing Climate Understanding for Policy: A Co-design Approach to Visualizing Temperature Overshoot

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Abstract

As the world approaches 1.5°C of global warming, understanding 'temperature overshoot' – temporarily surpassing and then returning below this threshold – has become vital, but remains poorly communicated. To address this, leading climate scientists and information designers from InfoDesignLab co-created a visual communication toolkit as part of the Annual Review paper *Overshoot: A Conceptual Review of Exceeding and Returning to Global Warming of 1.5°C*. Through an iterative co-design process, scientists, designers, and other actors collaborated from the start, using information design and data visualization not just to illustrate results, but to shape the scientific narrative itself. This project demonstrates how a design-led process can impact the communication of a scientific concept, fostering shared mental models and better-informed policymaking. Embedding professional design early in scientific workflows enables deeper engagement, clearer insight, and more effective communication at the interface of science, policy, and society.

Keywords: Climate overshoot, co-design, data visualization, information design, science communication.

Introduction

As the world moves steadily closer to exceeding 1.5°C of global warming, policymakers face one of the most complex and urgent challenges of our time: understanding not only what happens when this critical threshold is surpassed, but also how humanity might return again below it. This concept – known as *temperature overshoot* – is gaining prominence in climate policy discussions. Yet despite its growing importance, the term remains under-communicated, inconsistently defined, and poorly understood, even among experts deeply involved in climate research.

The scientific community has long discussed overshoot scenarios as theoretical pathways in climate models. However, as emissions continue to rise and progress towards mitigation goals slows, the likelihood of actually experiencing overshoot within this century has become increasingly real. The magnitude and duration of this exceedance matter enormously: while the world may temporarily rise above 1.5°C, sustained global efforts could, in principle, bring temperatures back below this level before the end of the 21st century. The trajectory of passing beyond 1.5°C and later returning defines what is referred to as an *overshoot pathway*. Even if temporary, such exceedance carries profound and irreversible risks. Ecosystems may collapse, species may be lost forever, and vulnerable communities – particularly those least responsible for climate change – may suffer damages that cannot be undone. Recognizing that overshoot is increasingly probable is not a justification for delay; it is an urgent call for faster and deeper action. Every tenth of a degree above 1.5°C makes returning more difficult and locks in additional impacts.

Understanding overshoot is therefore not a purely academic exercise. It touches directly on how science, communication, and policy intersect to shape global climate decisions. This project, described below, set out to make that understanding more coherent – using co-design and information design as integral parts of the scientific process itself.

Image 1: This paper proposes a co-design approach to visualizing the temperature overshoot concept. Credit: InfoDesignLab

Summary

The lack of shared mental models around the term 'overshoot' prompted a unique collaboration between an international team of climate scientists and design experts, many of whom were involved in the Intergovernmental Panel on Climate Change (IPCC) assessments. Their joint effort resulted in *A Conceptual Review of Exceeding and Returning to Global Warming of 1.5°C*, published in the 2025 edition of *Annual Review*.

This review consists of an article and five data visualizations that were not developed separately but *co-evolved* through a deeply collaborative process. Each visualization informed the written article, and the article in turn shaped each figure. The goal was to create a single, integrated communication product capable of helping policymakers, scientists, and other actors to build a shared understanding of overshoot—a concept central to contemporary climate policy.

While scientific literature on overshoot exists, this project was the first to synthesize its implications conceptually, connecting physical science, risk assessment, and social dimensions into one coherent framework. The work was conceived not as an after-the-fact illustration of existing research, but as a simultaneous act of designing and reasoning. Through repeated cycles of dialogue, critique, and refinement, the figures and text shaped each other, resulting in a unified representation of a complex and urgent issue.

The review and its accompanying visual toolkit target the communities that most directly influence international climate action — particularly IPCC authors and UNFCCC delegations. By translating abstract and technical concepts into accessible and structured narratives, the work aims to support more consistent and informed discussions among those responsible for setting global policy.

Importantly, the visualizations were designed not only for inclusion in the *Annual Review* paper but as the foundation for a communication platform. This evolving platform will continue to provide accessible, science-based insights on temperature overshoot and its implications for risk, adaptation, and mitigation. It aims to bridge research, public awareness, and policy action through carefully designed visual storytelling and evidence-based communication.

The Overshoot Narrative in Five Visualizations

The project produced the first comprehensive conceptual review exploring the implications of temperature overshoot pathways, identifying both evidence and knowledge gaps that illustrate the complex choices and trade-offs facing decision-makers.

The visual toolkit that accompanied the review aimed to explain, in clear and connected terms, what temperature overshoot means, what it implies for climate risk, and what options exist for returning to safer temperature levels. Each visualization captured one essential conceptual message, yet all five together formed a coherent narrative arc — each representing a stage in the broader story of exceedance and return.

The Five Visualizations

Figure 1 — Intent: In an overshoot pathway, temperature first exceeds a specified level of global warming and then returns to or declines below that level again within a specified time period. This visual has three conceptual panels. The left contrasts three temperature stories: staying below 1.5°C, exceeding and staying above 1.5°C, and exceeding then coming back down (overshoot). The middle compares two overshoot cases to show how magnitude (how far above 1.5°C) and duration (how long) can differ. The right links those temperature paths to global CO_2 emissions, highlighting the importance of reaching net-zero and then net-negative. Bigger and longer overshoots generally mean later net-zero and deeper net-negative CO_2. Together, the panels show why timing and scale of action matter (Reisinger et al. 2025).

Figure 1: The project's first visualization. Credit: InfoDesignLab

Figure 2 — Intent: Climate risk will differ, and mostly be higher, in an overshoot world where global warming exceeds 1.5°C and then declines below that level, compared with a world where warming never exceeds 1.5°C. This figure uses a "risk propeller" to compare three worlds: never exceed 1.5°C, exceed and return, and permanent exceedance. Each propeller blade represents a driver of risk — hazard, exposure, vulnerability, responses. Four example panels show how these drivers can shift by system or region. Sometimes hazards fall after overshoot, but vulnerability remains higher; sometimes hazards keep rising (e.g., with sea level); sometimes mitigation responses add pressure (e.g. land competition); sometimes adaptation lowers risk. Overshoot usually raises risk versus never exceeding 1.5°C, but is generally better than staying above it permanently, with reasons varying by context (Reisinger et al. 2025).

Figure 2: The project's second visualization. Credit: InfoDesignLab

Figure 3 — Intent: Even though global temperature is expected to decline linearly with net negative CO_2 emissions, that does not mean that other aspects of the Earth System also immediately decline. The visual uses combined temperature-emissions panels with annotated examples to show lag effects. The top panel shows a near-linear link between cumulative CO_2 and global temperature: once emissions go net-negative, temperature can gradually fall. The lower panels show how other Earth system components may not reverse fully or concurrently with global temperature. Arctic sea ice may recover, but with a delay. Ecosystems may see some reversals, yet past shifts can stick, and crossing thresholds may make change irreversible. Sea level keeps rising for centuries to millennia due to ocean heat and ice melt; cooler temperatures only slow the rise. In short, bringing temperatures down does not instantly rewind impacts — some respond slowly, some not at all (Reisinger et al. 2025).

Figure 3: The project's third visualization. Credit: InfoDesignLab

Figure 4 – Intent: There are three different types of mitigation efforts that can achieve a decline in temperature after a peak in an overshoot scenario. This visualization contrasts a world that stabilizes above 1.5°C with three illustrative overshoot pathways that peak near 1.7°C and return to 1.5°C by 2100. The middle panels unpack how each option combines gross CO_2 cuts, CO_2 removals, and non-CO_2 changes to reach net-zero and then net-negative. The bottom panels summarize the trade-offs: different amounts of methane in 2100, different cumulative gross CO_2 and carbon-dioxide removal (CDR) this century, and different levels of net-negative CO_2 after net-zero. The takeaway: multiple strategies can lower temperature after a peak, but they imply distinct timelines and resource demands (Reisinger et al. 2025).

Figure 4: The project's fourth visualization. Credit: InfoDesignLab

Figure 5 – Intent: The journey through overshoot is not a single decision but rather a complex path with different motivations and pressures pulling in multiple directions. In this visualization, drivers and tensions are mapped rather than prescribing a single route. Decision-makers must weigh costs, feasibility, fairness, technology, land and energy limits, adaptation needs, and societal preferences – often at the same time. Vertical markers indicate possible moments to accelerate the return below 1.5°C, but choices are interlinked: pushing mitigation can affect land and food; scaling CDR interacts with ecosystems and equity; investing in adaptation changes vulnerability and risk. The core message is practical: navigating overshoot requires simultaneous, integrated decisions on mitigation, adaptation, and resilience, acknowledging different capabilities and responsibilities while managing trade-offs and seeking synergies (Reisinger et al. 2025).

Figure 5: The project's fifth visualization. Credit: InfoDesignLab

Figures 6-10: Together, these visualizations function as a framework for reasoning about overshoot. Credit: InfoDesignLab

Beyond their immediate use in the context of the *Annual Review* article, these figures will serve as a foundation for an accessible online platform designed to evolve over time. The platform will integrate new data, highlight emerging research, and provide policymakers and the public with a coherent entry point into a concept that will increasingly shape climate discourse (CMCC Foundation 2025).

An Alliance of Scientists and Designers

Building on long-standing collaborations within the IPCC process, the design project was carried out by InfoDesignLab in partnership with an international network of scientists from leading research institutions.

The author group included several contributors and vice-chairs of IPCC working groups, alongside researchers with backgrounds in climate modelling, adaptation, mitigation, and communication.

The review was authored by Andy Reisinger, Institute for Climate, Energy and Disaster Solutions, Australian National University, Acton (Australia); Jan S. Fuglestvedt, CICERO – Center for International Climate Research, Oslo (Norway); Anna Pirani, Euro-Mediterranean Center on Climate Change – CMCC Foundation, Venice (Italy); Oliver Geden, German Institute for International and Security Affairs, Berlin (Germany); Chris D. Jones, Met Office Hadley Centre, Exeter (United Kingdom) and School of Geographical Sciences, University of Bristol, Bristol (United Kingdom); Shobha Maharaj, Ecological and Climate Crises Legal Institute – ECCLI, University of Fiji, Saweni, Lautoka, (Fiji) and Institute for Small Islands, Port of Spain (Trinidad and Tobago); Elvira S. Poloczanska, Integrative Ecophysiology; Alfred Wegener, Institute for Polar and Marine Research, Bremerhaven (Germany), Current address: Plymouth Marine Laboratory, Plymouth (United Kingdom); Angela Morelli, InfoDesignLab, Oslo (Norway); Tom Gabriel Johansen, InfoDesignLab, Oslo (Norway); Carolina Adler, Mountain Research Initiative, c/o Centre for Development and Environment, University of Bern, Bern (Switzerland); Richard A. Betts, Met Office Hadley Centre, Exeter (United Kingdom) and Global Systems Institute, University of Exeter, Exeter (United Kingdom) and Sonia I. Seneviratne Institute for Atmospheric and Climate Science, ETH Zurich, Zurich (Switzerland).

The design and facilitation were led by Angela Morelli and Tom Gabriel Johansen of InfoDesignLab – award-winning information designers internationally recognized for their work at the intersection of climate science, policy, and visual communication.

The mix of disciplines created a space where scientific precision met design sensitivity. Scientists brought deep domain knowledge; designers added facilitation, practical methods for collaborative thinking, and expertise for turning complex evidence into visual narratives.

Co-design as a Process

At the heart of the review lies data visualization – not as a decorative or surface-level instrument, but as a participatory and iterative process integrated early and continuously throughout the scientific workflow. The goal was not only to illustrate the findings but to shape how the findings themselves were conceptualized and communicated.

The approach drew on the co-design principles articulated by Sanders and Stappers (2008), where scientists, designers, and potential users participate as equal collaborators in creating communication tools.

The design and facilitation unfolded through overlapping streams:

- Facilitation of the co-design process.
- Development and refinement of intent for each visualization.
- Construction of a coherent visual narrative.
- Hands-on design and prototyping.

The process advanced through iterative cycles of workshops, reviews, and feedback sessions. Facilitation ensured that scientists played an active role in identifying key messages, refining terminology, and securing conceptual coherence. Design and manuscript development ran in parallel, each informing the other. This mutual shaping demonstrated how collaboration can influence scientific reasoning itself, not just its presentation.

Each iteration – referred to internally as Cycles A, B, and C – included definition of intent, visual prototyping, structured feedback, and refinement. The intent was defined as the goal each visualization needed to achieve, captured in plain language rather than technical language. It expressed the 'big idea' – the key pattern the audience should grasp instantly.

Once the intent was clear, the visual narrative was built – the journey that would lead readers to that understanding. The team asked: What should be seen first? How should attention move? Where should comparisons occur? These questions guided spatial layout, colour use, annotation, and hierarchy.

During workshops, scientists were often invited to present a future visualization as if it already existed – explaining its intent, data, and takeaway to a lay audience. These exercises exposed tacit assumptions, aligning mental models and revealing conceptual gaps early.

From these sessions emerged short 'stage scripts' for each figure – concise descriptions outlining what would be shown, the encoded variables, and the intended pattern. The scripts served as bridges between narrative and design, helping translate verbal insights into visual form. As soon as the team wrote a script, the hierarchy of information became clearer: what supported the intent, what distracted from it, and where the narrative peak should sit. Wireframes followed naturally.

The co-design process was therefore not a linear path from concept to completion but an iterative journey of discovery and clarification. Each visualization acted as a milestone for reflection, allowing authors to view the content from different perspectives and strengthen both scientific and communicative coherence.

Because many of the scientists were themselves part of the target audience, their dual role as content experts and end-users added value to the process. Through these shared design spaces, the team identified the visual and conceptual pillars of the review and aligned them with the manuscript's evolving structure.

The Upstream Value of Information Design within Science

While the focus of the review was temperature overshoot, the deeper contribution lies in demonstrating the transformative value of co-design within scientific communication.

In most research contexts, design and communication are treated as downstream activities — commissioned after the science is complete. This project inverted that paradigm by embedding design from the outset, integrating it directly into the scientific reasoning and authorship process.

The co-design model moved beyond the traditional 'designer as translator' role toward a shared creative process where intent, audience needs, and scientific accuracy are intertwined in real time. This model provides a blueprint for how complex science–policy topics can be collaboratively developed.

The overshoot case illustrates how embedding information design early in a scientific project clarifies concepts, reveals hidden assumptions, and strengthens communication outcomes. By turning abstract findings into visual frameworks, the process enhanced internal alignment among scientists.

After the publication of the *Annual Review* article, the same visual and conceptual frameworks became the starting point for a new co-design process that landed on a double-spread article in *Scientific American*. This translation demonstrated that co-designed visuals developed within scientific workflows could be recontextualized for wider audiences without losing precision. The process confirmed that co-design is a powerful bridge between expert understanding and public communication, maintaining conceptual integrity while enhancing accessibility.

More broadly, the project confirms that the co-design of complex information can help scientific organizations build stronger communication capacity. When scientists, communicators, and designers collaborate from the beginning, the results are not just clearer outputs but more coherent thinking about the problem itself.
For research funders and consortia, this case highlights the need to explicitly include information design expertise in project planning and budgeting. Co-design requires time, facilitation, and iterative engagement — it cannot be reduced to a rapid, decorative task. Its benefits, however, extend far beyond the individual project, influencing how institutions think about clarity, participation, and knowledge sharing (Morelli et al. 2021).

Conclusion

In a world where misinformation and disinformation are among the top threats to democratic processes and evidence-based decision-making, the capacity to communicate scientific complexity with clarity and relevance to those who must act upon it has never been more critical.

Information design offers a pathway to unlock the full potential of scientific evidence by transforming data into meaningful and actionable insight. Yet this transformation requires that design be understood as a process, not a finishing touch. It involves continuous dialogue, cross-disciplinary empathy, and deliberate attention to how audiences interpret information.

A participatory and collaborative design approach supports understanding because it focuses on *interpretation* — on how ideas live in the minds of people. Behind what we call 'audiences' are diverse human beings with distinct experiences and values. Ignoring these perspectives risks confusion, miscommunication, and polarization.

Embedding information design within scientific workflows is therefore not an optional luxury but a necessity. It is a specialized professional practice that demands leadership, time, and intentional planning. When information designers are integrated from the start, they act not merely as illustrators but as facilitators of understanding — helping teams navigate uncertainty, align intent, and build tools that genuinely support decision-making.

The experience of this project shows that co-design enhances both science and communication. It helps scientists reflect on their assumptions, reveals gaps in reasoning, and produces shared visual languages that endure beyond individual papers. The co-designed overshoot visuals now form the basis of a communication platform linking science, policy, and society — an example of how iterative collaboration can extend the life of research and reach.

By professionalizing design practice within science-policy spaces, decision-makers can gain not only better visuals but a deeper and more actionable understanding of climate risk. Designers, when empowered to work alongside scientists, become translators of complexity and co-creators of meaning.

Ultimately, the lesson from this collaboration is that understanding and intentionally combining design and scientific processes can transform how complex evidence is produced and communicated. Co-design offers a framework through which uncertainty can be discussed, consensus can be built, and shared understanding can emerge.

In facing the challenges of the 21st century — climate change, health, inequality — the capacity to co-create meaning will be as important as the capacity to generate data. Information design, when embedded within science, helps ensure that knowledge does not remain confined to experts but becomes a tool for collective intelligence and informed action.

As we reflect on the role of information design, it becomes clear that our profession must now meet its own moment of truth. It is time to step closer to the fire, to take responsibility, get our hands dirty, and walk alongside scientists rather than orbit around them. Doing so requires more than aesthetic sensitivity; it demands curiosity, discipline, and a willingness to engage deeply with the science itself. We must dig into the subject matter we seek to visualize and, at the same time, into the complexity of the minds who need to understand it. We cannot design what we do not understand. To serve science and society well, we must embrace the hard, beautiful work of understanding both.

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Designing Policy for Impact: A Knowledge Platform to Advance Sustainable Urban Development in Brazil

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Abstract

This paper explores the role of interface design in enhancing user experience on knowledge platforms focused on urban sustainability. Drawing on the author's coordination of the Observatory of Innovation for Sustainable Cities (OISC) and a comparative analysis of 30 international observatories, the study proposes a new model structured around four urban scales: home, street, neighbourhood, and city. The research highlights the integration of information architecture and interface design as key elements for accessible, inclusive, and participatory digital environments. The proposed platform emphasizes three pillars – support, promotion, and education – and incorporates user-centred and responsive design strategies. This approach aims to foster civic engagement, improve access to sustainability data, and support evidence-based decision-making for public managers, researchers, and citizens. The project contributes to the broader discourse on smart urban development by demonstrating how digital tools can improve knowledge dissemination and help shape resilient and sustainable cities across different regional contexts in Brazil.

Keywords: Civic engagement, information architecture, interface design, knowledge platforms, sustainable urban development.

Introduction

The process of urbanization in Brazil has contributed to the intensification of various challenges related to urban sustainability, including issues concerning mobility, housing, infrastructure, and the management of natural resources. Although access to qualified information is an essential component in the formulation and implementation of effective public policies, there remains a significant limitation in how such data is organized, made available and communicated to society.

Urban observatories, as platforms for monitoring and disseminating information related to public policies and urban indicators, hold considerable potential to support decision-making across multiple spheres. However, many of these instruments present usability limitations in their interfaces, which undermines their capacity to promote citizen engagement and support informed action by public managers.

In this context, interface design becomes increasingly relevant as a structuring element in the development of digital environments that are more accessible and user-oriented. Well-designed interfaces improve navigation, facilitate the appropriation of information, and serve as a bridge between technical data and its practical application in the urban context.

Research Objectives

This study aims to analyze the role of interface design in enhancing user experience on knowledge platforms focused on urban sustainability. The research draws upon the experience of the Observatory of Innovation for Sustainable Cities (OISC), coordinated by the author between 2019 and 2022, in addition to a comparative analysis of 30 national and international urban observatories.

The central objective is to discuss the organization of information through a structure based on four urban scales – home, street, neighbourhood, and city – in order to enhance contextual understanding of data and support the adoption of solutions aimed at sustainable urban development.

Background and Theoretical Context

Knowledge platforms enable the integration, organization, and dissemination of information in accessible and collaborative ways. They seek to facilitate interaction among various social actors, such as researchers, public managers, companies and citizens, promoting the creation and sharing of knowledge efficiently and inclusively. According to Davenport and Prusak (1998), organizational knowledge is a strategic resource, and digital platforms assist in the management of this knowledge.

Manuel Castells (1996) discusses how contemporary society is structured around networks of information. Castells emphasizes that information is the raw material of the digital age, and its access is essential for the economic, social and cultural development of cities. According to Castells, knowledge platforms must function as networks that connect different social actors, facilitating information exchange and collaboration among them. This interconnection is particularly relevant for observatories of sustainable cities, where data integration and collaboration among diverse actors are fundamental to addressing complex and dynamic urban challenges.

Vassão (2024) addresses a new topic for cities that aligns with the development of knowledge platforms. He explores how design can transform cities into spaces more centred on the needs of citizens. His work examines the evolution of design from the creation of accessible digital interfaces to the promotion of digital transformation. It is highlighted that design must go beyond technology, encompassing social and organizational relationships, and presents the concept of *Metadesign*. This concept views the city as an artifact co-created by society, emphasizing collaboration and citizen participation.

During the 1990s and 2000s, the evolution of internet technologies and mobile devices brought new challenges and opportunities for interface design. Shneiderman and Plaisant (2010) emphasized the need for user-centred design that allows intuitive navigation and reduces the occurrence of errors. Alan Cooper (2014), another influential theorist, introduced the concept of personas in interface design. This method helps designers focus on the specific needs of representative users, improving the relevance and usability of designs.

The importance of multiscalar information design is exemplified in international observatories and city platforms in Barcelona (Spain), Medellín (Columbia), Helsinki (Finland) and Amsterdam (The Netherlands). In Barcelona, the post-1992 Olympics transformation merged physical renewal with civic engagement through participatory urban design and territorial requalification. Medellín's Metrocable integrated transport with social inclusion, redefining mobility and equity through infrastructure as an agent of transformation. Both cases reflect how digital and spatial design converge to foster trust and shared urban vision. In Helsinki and Amsterdam, extensive investments in open data portals and participatory dashboards have created robust feedback loops that ensure continual refinement of user experience and governance transparency. Rather than static repositories, these platforms function as dynamic ecosystems embedded in the daily lives of citizens, which demonstrates the importance of interface design as a strategic layer in sustainable urban governance.

In the context of knowledge platforms for cities, interface design plays a key role in facilitating citizen interaction with urban data. The implementation of advanced technologies demands interfaces capable of supporting the visualization and interpretation of large volumes of data. These interfaces should be designed to be intuitive, providing users with relevant information in a clear and accessible manner. Furthermore, knowledge platform interfaces must be adaptable and responsive, allowing access from a variety of devices such as computers, tablets and smartphones. Responsiveness ensures a consistent user experience regardless of the device used, which is especially relevant in urban environments where citizens often access information on the move.

Research Methodology

To develop the product of this study, an exploratory and qualitative methodology was adopted, composed of sequential and interconnected stages. The methodology was structured across three main areas: interface design, information architecture and platform content, with an emphasis on comparative data between the selected observatories and the Observatory of Innovation for Sustainable Cities (OISC).

The first step involves presenting the OISC, detailing its objectives, content and interface structure to allow global contextualization in relation to other urban observatories. The platform's connection with the United Nations Sustainable Development Goals (UN SDGs) is highlighted, as well as its objective to promote sustainable innovations in Brazilian cities through a knowledge platform that facilitates the exchange of information and dissemination of best practices.

Subsequently, the selection of observatories to be analyzed was defined. A total of 30 observatories were selected based on the following criteria: relevance in the field of urban sustainability, geographic diversity, and alignment with the UN SDGs. The selection also considered observatories that demonstrated practices compatible with, or aligned with, key objectives established by the UN, such as sustainability, social inclusion, equity, international collaboration, technological innovation, transparency and open data access.

Data collection and analysis were conducted along three main axes:

1. Interface design: the analysis of the interface design of the observatories focused on the aesthetics, functionality and usability of the platforms. Manual navigation through each platform allowed for an assessment of visual clarity, interactivity, and ease of use. Aspects such as layout of on-screen elements, menu intuitiveness, and responsiveness of the navigation systems were considered.
2. Information architecture: the evaluation of information architecture included the analysis of the organization, structuring, and labelling of content. This examination involved the creation of sitemaps and the analysis of wireframes and taxonomies to understand how information is presented and organized for users. The analysis of the information architecture focused on navigation efficiency and clarity of content categories and subcategories (Garrett 2020; Morville 2010).
3. Platform content: data collection regarding the practices and solutions implemented by each observatory involved analyzing the types of data presented, data collection methodologies and frequency of updates. The comparative analysis considered sustainability indicators defined by the United Nations, such as solid waste management, air quality, green spaces, disaster resilience, sustainable mobility and water resource management. Community engagement policies and environmental education initiatives promoted by the observatories were also examined.

Mapping and Analysis of Observatories

The comparative analysis of the observatories enabled the identification of best practices, limitations and opportunities for improvement. The aim was to propose a new platform model adapted to Brazilian regional realities, focusing on inclusion, accessibility and civic participation. This methodological approach seeks not only to evaluate existing platforms but also to provide practical inputs for the redesign of urban observatories, contributing to the strengthening of urban governance and the promotion of sustainable development.

1	Analysis and Policy Observatory 2 - CDP (Carbon Disclosure Project)	16	Institute for Future Cities
3	Centre for Public Impact	17	IRCS - International Research Center on Sustainability
4	City Form Lab	18	LABSIMURB
5	City Observatory (UCLG)	19	National Institute of Urban Affairs
6	EIXOS	20	Observatics - Observatorio de Sociedad, Gobierno y Tecnologías de Información
7	ELTIS - The Urban Mobility Observatory	21	OBSERVATORIO CITé
8	European Innovation Partnership on Smart Cities and Communities	22	Observatório das Favelas
9	France Ville Durable - Sustainable City by France	23	Observatório das Metrópoles
10	Global Platform for the Right to the City	24	Huelva – America
11	Global Urban Observatory (GUO) UN habitat - ONU 12 – GORA	25	PASCAL International Observatory
13	Group on Earth Observations – GEO	26	SCO - Smart City Observatory
14	ICLEI - Governos Locais pela Sustentabilidade	27	SDG Knowledge HUB
15	Inclusive Cities Observatory	28	Smart Cities
		29	Urban Observatory
		30	Urban Proof (Climate Roofing Urban Municipalities)

Figure 1: Collected data prepared by the author showcasing the mapping of observatories.

Interface Design Evaluation Criteria

The evaluation of interface design was based on a set of specific criteria:

- Visual aesthetics and consistency: examines the use of colours, fonts, icons, and visual styles to ensure a coherent and appealing visual experience.
- Ease of use: evaluates the intuitiveness of interface elements and the quality of system feedback — factors that directly influence the learning curve and navigation efficiency.
- Responsiveness: analyzes the ability of interfaces to adapt to different devices and screen sizes, ensuring a consistent experience in all usage contexts.
- Accessibility: assesses the inclusion of users with disabilities, ensuring that everyone can interact properly with the platform.
- Interactivity: considers the clarity and functionality of interactive elements and the logical structure of navigation, enabling users to easily find the desired information.

The analysis revealed that many observatories need to improve accessibility and responsiveness, emphasizing the importance of designing interfaces for all. Observed practices serve as a model for other platforms aiming to improve their effectiveness in knowledge dissemination and stakeholder engagement.

A well-designed information architecture supports the success of knowledge platforms by ensuring that information is accessible, understandable, and usable by all users. The 30 cases analyzed were categorized to identify common characteristics, aligned with the OISC framework, including:

Origin, language (communication), founding year, mission, area of activity, type of operation, organizational structure, physical or online headquarters, format, number of collaborators, community involvement, initiative/nature (private, public, or hybrid), institutional/university partnerships, involvement in public policy, publication of reports, articles and data, use of secondary data, content themes, open data sharing, consulting services, monetization, social media presence, user engagement, in-person events, and the impact of their actions and how they are monitored.

The analysis of these platforms reveals a landscape of initiatives focused on promoting sustainability, social inclusion and smart urban development. These observatories function as knowledge platforms that collect, organize, and disseminate information to guide public policies and urban practices.

The complementary relationship — though still requiring improvement — between interface design and information architecture is evident in these platforms. Both aspects contribute to usability and efficiency in navigation and information access, as discussed in previous chapters. By comparing these initiatives with the Observatory of Innovation for Sustainable Cities (OISC), we can identify innovations to be adopted. Improvement areas include:

- Promotion of international partnerships to facilitate the exchange of best practices.
- Greater engagement in online events, such as webinars and virtual conferences, which proved effective on other platforms during the pandemic.
- Expanded partnerships with the private and academic sectors to develop applied research projects offering scalable solutions to urban challenges.
- Implementation of a continuous user feedback system to refine information architecture and improve platform usability, ensuring that stakeholder needs (institutions and partners) are pragmatically met.

From this analysis, it is clear that observatories and their knowledge platforms play a significant role in promoting sustainability, social inclusion and smart urban development. The integration of information architecture and interface design is essential to ensure that these platforms are accessible and useful to a wide range of users. Continuous innovation and learning from best practices across platforms support the development of more resilient and sustainable cities.

With the content defined, the next step was the creation of the information architecture. This phase involves logically and intuitively organizing and structuring the content to facilitate navigation and information access for users. Key components include a content hierarchy offering a clear definition of categories and subcategories:

- Intuitive navigation: development of a system that allows users to quickly find what they're looking for.
- Usability: ensuring all functionalities are accessible and usable by all users, including people with disabilities.
- Interactivity: implementation of tools that allow user interaction, such as discussion forums, rating systems, and interactive maps.

Finally, with the content and information architecture in place, interface design is the stage that consolidates the platform. This design should prioritize the user experience, ensuring a smooth and enjoyable interaction with the platform. Key elements include:

- Pleasant aesthetics: a visually attractive design reflecting the values of sustainability and innovation.
- Visual consistency: coherent use of colours, typography, and icons to facilitate recognition and navigation.
- Interactivity: interfaces that respond clearly and predictably to user actions.
- Responsiveness: ensuring the platform is accessible and functional across various devices, including smartphones, tablets, and computers.
- Project proposal: Observatory of Innovation for Sustainable Cities (OISC).

Platform Design Proposal

The final product proposal is the creation of an inclusive and accessible observatory called the Observatory of Innovative and Sustainable Cities. This observatory will be a comprehensive platform to promote sustainable urban development in Brazil, integrating advanced technological solutions, community engagement strategies and evidence-based public policies.

The focus will be on implementing sustainable practices across different urban levels, organized around the triad of support, promotion and education. The digital platform will be intuitive, accessible and adaptable to the needs of various Brazilian regions, offering educational resources, technical support, and campaigns to promote sustainability.

According to Tether (2021), public design policies must incorporate the elements of support, promotion, and education. These areas are essential for fostering an environment conducive to innovation:

- Support: policies that provide financial and technical support are crucial to encourage R&D and design activities. This includes subsidies, tax incentives, and funding programmes that help companies invest in innovation. Tether emphasizes that support must be accessible to organizations of all sizes, especially small and medium-sized enterprises that may lack the resources for significant innovation investments.
- Promotion: promoting design and innovation practices should be a priority. This involves awareness campaigns, networking events, and conferences that highlight best practices and success stories in the field of design. Promotion can transform attitudes and behaviours, encouraging more organizations to adopt new approaches.
- Education: investing in education and training is essential to sustain innovation over the long term. Educational programmes should be developed to train professionals in R&D and design. This includes technical training courses, undergraduate and graduate programmes, and specialized workshops.

The organizational structure of the Observatory of Innovative and Sustainable Cities was based on the same three pillars:

1. **Support**: the goal is to provide tools, data, and resources to assist in the implementation of sustainable practices at various urban levels. Key components include: a data centre functioning as a centralized repository of urban data, sustainability indicators, and case studies; visualization tools such as interactive dashboards and maps to facilitate data analysis and technical consultancy offering support services to local governments, NGOs and communities.
2. **Promotion**: this area aims to encourage and disseminate sustainable practices and initiatives through campaigns, events, and collaboration networks. Its components include: awareness campaigns to raise public consciousness about urban sustainability; events and workshops that promote knowledge exchange; collaboration networks connecting various actors (institutions and partners) to facilitate cooperation in sustainable projects.
3. **Education**: the objective is to empower citizens, public managers, and professionals in the urban sector through educational programmes and training materials. Components include: educational materials such as guides, manuals, and didactic content on urban sustainability; training programmes with courses for diverse audiences, including public administrators, professionals, and the general community; an e-learning platform offering online courses and educational resources.

In addition to Tether's adapted triad, the Observatory also emphasizes the importance of integrating the urban nuclei – your home, your street, your neighbourhood and your city – as these are the spaces where environmental, social and economic challenges manifest.

- Your home is the basic unit of urban structure and the starting point for sustainable practices. According to Newman and Kenworthy (2015), sustainable practices begin at home with the adoption of technologies and innovations for domestic use.
- Your street plays a crucial role in urban connectivity and mobility. They are the sites of daily interactions and are vital for social cohesion. Gehl (2010) argues that well-designed streets promote social interaction and inclusion, creating safe and pleasant environments for pedestrians.
- Your neighbourhood extends the home and the street, representing a community where residents develop identity and belonging. Well-structured neighbourhoods offer access to essential services – schools, markets, health centres and leisure spaces – all within walking distance. This encourages community life and reduces the need for long commutes, contributing to urban sustainability.
- Your city, as the macrostructure, is composed of the sum of homes, streets, and neighbourhoods. Efficient integration of these components provides the foundation for functional and sustainable urban systems. According to Lefebvre (1991), the city should be understood as a living space where the daily practices of citizens shape and are shaped by the urban environment.

The platform's interface design was developed based on user-centred design and accessibility principles, ensuring the tool is inclusive and usable by both experts and the general public.

- The choice of colours, typography and visual layout was carefully considered to minimize users' cognitive load and provide a pleasant, intuitive experience.
- Visual elements were selected to reinforce the project's identity, which centres on sustainability and citizen participation. The colour palette primarily features shades of green and blue, evoking environmental themes and establishing an emotional connection with the concept of sustainable development (Gehl 2010).
- Contrasting colours are used for action buttons to ensure easy identification and interaction, which is fundamental for usability.

Figure 2: Visual representation of the Observatory's structure created by the author using the Brasília Dingbats icon set.

Navigation icons representing each urban nucleus are designed to be simple and intuitive, allowing users to quickly understand their functions. This avoids visual overload and enhances option clarity. According to Norman (2013), well-designed icons are essential in helping users navigate systems without external instructions.

An essential stage in the platform development process was the creation of a mock-up, a simplified visual representation of the proposed idea. This low-fidelity prototype enables visualization of the platform's structure, key elements and expected functionalities. Though not the final version, the mock-up provides a preview of how ideas have been implemented thus far and how the platform can be used to achieve its goals (Garrett 2020).

The development of the Observatory aimed to provide a tool that connects citizens, public managers and researchers, promoting more efficient and transparent urban management in Brazil. Its organization into four distinct nuclei – city, neighbourhood, street, and home – allows users to gain a layered view of data, facilitating understanding of actions needed at each level.

This scalable model enables both a broad, integrated view of urban sustainability and detailed analyses that encourage specific, localized actions.

The platform's mock-up played a key role in validating initial hypotheses and aligning the interface with user expectations. From the mock-up, it became clear which elements were working as intended and which needed improvement. This validation process is critical in tech projects, as it helps prevent structural problems from persisting into the final version (Garrett 2020).

In addition, the platform stands out for its participatory nature. The inclusion of dedicated support, promotion and education sections for each level (city, neighbourhood, street, home) demonstrates the project's commitment to creating an educational and engaging interface.

Figure 3: Mock-up of the Observatory of Innovative and Sustainable Cities created by designer Ivan Sasha Stemler under the guidance of the author.

Conclusion

The proposed platform introduces the concept of an interactive urban observatory that facilitates the organization and visualization of complex data, supporting evidence-based decision-making.

In a context where many urban managers struggle to consolidate information and coordinate sustainability efforts, this platform offers a practical solution that can assist in the integration of public policies and monitoring of sustainability indicators. The modular approach in the information architecture allows the platform to be used by cities of varying sizes, adapting to specific local needs. Moreover, the user-centred interface promotes an accessible and inclusive navigation experience, making the platform suitable for both experts and non-specialists. This means the tool can support civic education, facilitating public understanding of sustainability challenges and solutions (Norman 2013).

The implementation of the platform presents several challenges that must be addressed to ensure the success of the initiative. One major issue is the integration of data from diverse municipal sources. Many municipalities have outdated or fragmented data collection systems, making it difficult to consolidate the necessary information for the platform to function effectively.

To overcome this, a collaborative effort will be required between local governments and the project's technical team to develop data standardization protocols, ensuring the quality and consistency of the information used.

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Designing with Trust, Dignity, and Resilience: A Participatory Framework for Culturally Rooted Public Health Policy in Rural India

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Abstract

This paper presents a participatory design framework that reimagines rural public health policymaking in India through the principles of trust, dignity, and resilience. Rooted in ethnographic and participatory fieldwork, the research investigates systemic gaps in the delivery and perception of health services among adolescent girls in Karnataka's Chamarajanagar district and marginalized communities across Tamil Nadu. Conventional top-down health interventions, though well-intentioned, often neglect local cultural realities, resulting in mistrust and disengagement. By integrating participatory and systemic design methodologies, this study reframes health policymaking as a relational process that prioritizes community co-creation and cultural specificity. This work contributes to discourses on design for social innovation, health equity, and participatory governance. It calls for embedding design liaisons in public institutions to foster community-led, culturally rooted, and resilient health systems that uphold the dignity of all citizens.

Keywords: Culturally rooted innovation, design for health equity, design for SDGs, participatory policy design, public health toolkit, rural resilience, systemic design, trust-based interventions.

1. Introduction

Public health interventions in rural India often operate through centralized, data-driven models that overlook local cultural nuances. Despite large-scale government efforts, many health programmes fail to achieve sustained impact because they do not align with the lived experiences and social dynamics of rural communities. The resulting disconnect generates mistrust and disengagement, particularly among adolescent girls and marginalized groups.

This research proposes a participatory design framework to reimagine public health policymaking as a co-created, context-sensitive, and culturally resonant process. The work draws on ethnographic immersion and participatory co-design in the states of Karnataka and Tamil Nadu to explore how design can build trust, uphold dignity, and foster resilience within public systems. Design, when embedded within policymaking, can act as a relational and ethical practice that bridges communities and institutions. It can create shared ownership over health systems, enabling citizens to become active participants in shaping the services that affect their lives. The paper positions design not as a tool for intervention delivery, but as a means of collective sense-making, governance, and social repair.

2. Background and Theoretical Context

2.1. Participatory Design and Health Policy

Participatory design (PD) originated in the Scandinavian labour movements to democratize technological decision-making. Over time, it has evolved into a global practice that values user agency and co-creation. In the domain of public policy, PD offers a way to bridge institutional objectives with citizen realities. However, in many Global South contexts, policymaking remains largely technocratic and hierarchical, leaving little space for community participation.

In India, while programmes such as UNICEF's Communication for Development (C4D) and Participatory Rural Appraisal (PRA) have emphasized community engagement, these approaches often stop short of influencing actual policy design. This gap leaves local voices underrepresented in governance processes.

2.2. The Role of Systemic Design

Systemic design merges systems thinking with participatory design to address complex, interdependent problems. In public health systems, this approach allows designers to visualize feedback loops, map relationships among stakeholders, and identify leverage points where interventions can generate long-term systemic change. It acknowledges that public health challenges are not isolated technical deficits but outcomes of cultural, institutional, and infrastructural misalignments.

2.3. Trust, Dignity, and Resilience as Design Values

Trust, dignity, and resilience are often overlooked in service design yet are critical to public health success. Trust ensures relational accountability between institutions and citizens. Dignity affirms that people's experiences and cultural knowledge are respected and embedded in policy design. Resilience enables health systems to adapt to socio-political changes while maintaining ethical grounding. These three values form the ethical and methodological foundation of the proposed framework.

3. Methodology

The research combined ethnographic, participatory, and systemic design approaches. Fieldwork was conducted across a few districts: Chamarajanagar in Karnataka and Thiruvannamalai in Tamil Nadu. These sites were chosen for their diverse cultural contexts and visible inequities in healthcare access.

The study unfolded in three stages: (1) immersion and fieldwork, (2) participatory co-design, and (3) toolkit development and validation.

3.1. Immersion and Ethnographic Inquiry

Researchers engaged with adolescent girls, caregivers, ASHA and Anganwadi workers, nurses, and doctors. Methods included semi-structured interviews, shadowing, and informal conversations. The emphasis was on listening, not extracting, allowing participants to shape the inquiry through their own experiences and expressions.

Through these interactions, patterns emerged: adolescent girls faced barriers in discussing menstruation and nutrition due to social taboos; visual and linguistic disconnects in health materials alienated users; and community health workers struggled with the mismatch between institutional expectations and cultural contexts.

Image 1: Participatory research activities with the adolescent girls of Chamarajanagar (India).

3.2. Participatory Co-design

Co-design workshops and dialogue circles were held in collaboration with local organizations. Participants used visual prompts, storyboards, and mapping exercises to reimagine how health communication and service delivery could better reflect local realities. These sessions emphasized horizontal learning and collective authorship.

Activities included:

- Designing menstrual education materials using local idioms.
- Creating community maps showing informal care networks.
- Designing low-tech preventive menstrual products using local knowledge.

Image 2: Participatory workshop designing with the gynecologists.

3.3. Systems Mapping and Analysis

Using stakeholder maps and causal loop diagrams, the research identified systemic gaps and leverage points. Service blueprints revealed the disjuncture between formal policy structures and the informal care networks communities rely on.

Research ethics followed participatory principles: informed consent through storytelling, anonymity, reciprocity, and reflexivity. Reflective journaling and regular consultations with local partners ensured accountability.

4. Field Contexts and Key Insights

4.1. Karnataka: Adolescent Health and Bodily Autonomy

In Chamarajanagar, adolescent girls described discomfort in accessing health services due to cultural taboos surrounding menstruation and bodily autonomy. Many educational materials used urban-centric illustrations or medicalized language, which made girls feel judged or embarrassed. ASHA and Anganwadi workers often mediated these sensitivities through informal counseling, though without institutional recognition or training.

4.2. Tamil Nadu: Structural Inequities and Cultural Knowledge

In the Tamil Nadu districts, fieldwork revealed additional barriers related to caste hierarchies, gender norms, and infrastructural neglect. Long travel distances to clinics and lack of women doctors limited access. Despite the existence of traditional health knowledge around nutrition and herbal care, these practices were dismissed as unscientific, eroding local agency.

4.3. Insights across Contexts

Across regions, adolescent voices remained marginalized in both policy and domestic spaces. The study found that resistance to government health programmes often stemmed not from ignorance but from a lack of emotional safety and cultural resonance. Communities desired participation, not prescription.

These findings reframed the challenge: public health design must shift from informational delivery to mutual learning and co-sensing, recognizing emotional, cultural, and relational dimensions as central to systemic resilience.

5. The Community-responsive Public Health Toolkit

The Community-responsive Public Health Toolkit was developed to address these systemic and cultural disconnections. It positions communities as active co-designers of policy rather than passive beneficiaries. The toolkit's structure is built around four interdependent pillars.

5.1. Problem Sensing with Communities

Instead of defining health issues through quantitative metrics, this pillar focuses on collective sense-making. Methods include participatory mapping, storytelling circles, and community timelines. These reveal how communities define well-being in their own terms and expose emotional and relational barriers often hidden from policymakers.

5.2. Culturally Anchored Co-design

Building upon the insights gathered, stakeholders co-create health materials and service experiences grounded in local culture. Examples include menstrual health kits using indigenous cloth-making techniques, illustrated guides in local dialects, and visual metaphors drawn from folk traditions. This process builds emotional connection and cultural ownership.

5.3. Policy Translation through Narrative Prototyping

To bridge community insights with institutional language, experiences are transformed into narrative policy prototypes such as comics, illustrated briefs, and scenario walk-throughs. Policymakers participated in these exercises to develop empathy for users' lived experiences and to translate narratives into actionable guidelines.

5.4. Iterative Field Validation

Policy is treated as an evolving process rather than a static document. Interventions were tested through community sessions, mobile reflection booths, and feedback via WhatsApp groups. Continuous validation enabled adaptation to changing contexts and strengthened mutual accountability.

5.5. Toolkit Components

Image 3: Context to care, toolkit for the frontline workers.

The toolkit consists of several modular instruments:

- **Community journey maps**: tracing health experiences across touchpoints.
- **Empathy probes**: diaries, sensory prompts, and conversation cards.
- **Visual vocabulary templates**: co-developed symbols and icons for culturally rooted communication.
- **Narrative policy cards**: storytelling-based translation of field insights into policy actions.
- **Facilitation scripts**: guiding frontline workers in conducting respectful, empathetic conversations.

These tools are open-source, adaptable, and designed for use by NGOs, public institutions, and academic researchers.

6. Discussion

The proposed framework challenges traditional notions of health policy by centring community knowledge as a legitimate and essential source of design intelligence. It shifts the designer's role from expert problem-solver to facilitator of dialogue, care, and co-governance.

What policymakers often interpret as 'non-compliance' is revealed to be resistance to misaligned systems. When communities disengage, it is often because their dignity and local knowledge have been ignored. Participatory design reframes this resistance as valuable feedback that exposes ethical and cultural blind spots.

Implementing participatory methods in bureaucratic systems is not without challenges. Institutional structures prioritize scale, efficiency, and risk aversion, while participatory approaches require time, empathy, and flexibility. However, small steps, such as co-developing visual materials or involving ASHA workers in policy brainstorming, can significantly enhance inclusivity and sustainability.

Beyond health, the framework offers insights for governance more broadly. It resonates with movements in design justice, decolonial governance, and participatory democracy that advocate for equitable power distribution and shared authorship in decision-making.

The framework thus transforms policy into a living, relational system, where trust replaces authority, participation replaces compliance, and care becomes a foundation for resilience.

7. Implications for Policy and Design Practice

For **policymakers**, this research suggests three actionable directions:

1. **Institutionalize participatory roles**: embed design liaisons or participatory design units within public health departments to facilitate ongoing community engagement.
2. **Integrate continuous feedback**: establish iterative validation mechanisms where community feedback shapes every policy cycle.
3. **Recognize cultural knowledge**: treat vernacular knowledge, symbols, and rituals as data for policymaking, not as cultural artifacts.

For **designers**, the research calls for humility and commitment:

1. **Design with, not for**: co-create at the community's pace and comfort level.
2. **Value process over output**: treat toolkits as processes of relationship-building rather than deliverables.
3. **Design for listening**: create infrastructures that enable dialogue and trust.

8. Conclusion

This paper repositions public health policymaking as a participatory, relational, and culturally grounded design process. Through fieldwork in Karnataka and Tamil Nadu, it demonstrated how trust, dignity, and resilience can transform health systems when communities are treated as co-authors of change.

The Community-Responsive Public Health Toolkit operationalizes this vision through problem sensing, culturally anchored co-design, narrative translation, and iterative validation. It shows that when policies emerge from within communities, they carry both ethical and systemic strength.

Ultimately, this work argues that effective health systems must not only be efficient but also empathetic, not only data-driven but also meaning-driven. Participatory design, when practiced with care, humility, and reflexivity, becomes a method of justice — one that restores agency, nurtures resilience, and designs hope into governance.

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Involving Residents in Climate-adaptive Urban Development: Lessons Learned from The Netherlands

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Abstract

As climate change intensifies, resident engagement in Dutch climate-adaptive urban development has shifted from top-down consultation to participatory co-creation and community-driven initiatives. Climate change is felt and dealt with locally; this makes resident perspectives and engagement more valuable than ever. Design has emerged as a critical connector between residents and governments, translating local needs into policy goals while fostering trust, collaboration and shared ownership. Design methodologies play a pivotal role in this transition acting as a connector, aligning governmental ambitions with resident needs. This paper explores four case studies from The Netherlands that illustrate different ways of how residents can be deeply involved in climate-adaptive urban development. Overarching themes are drawn from these cases and shared as transferable applications to inspire other similar ambitious projects.

Keywords: Climate adaptation, climate resilience, co-creation, do-democracy, governance, participatory design, resident engagement, The Netherlands, urban development.

Introduction: Climate Change Calls for New Participatory Methods

Climate change is experienced most directly at the local level, sometimes even at the neighbourhood level. While national and municipal governments can map risks and track broad patterns, the lived reality of flooding, heat stress, or drought is felt firsthand by residents themselves. Their perspectives and engagement are therefore essential to creating effective adaptation strategies that respond to the specific needs and vulnerabilities of the community.

Resident knowledge, concerns, and aspirations shape how climate measures succeed on the ground. And local action has the power to complement broader policy frameworks. Meaningful resident engagement around climate adaptation requires approaches that connect, inform, and motivate citizens in ways that feel relevant and accessible. This calls for inclusive and engaging participatory methods that prioritize bottom-up collaboration and support. Design's emphasis on empathy, creativity and problem-solving offer powerful tools to foster these connections and strengthen climate adaptation at the neighbourhood level; these participatory methods enable complex challenges to be translated into action.

The Dutch Context

The Netherlands faces unique vulnerabilities to climate change due to its geography, with one-third of the country lying below sea level and much of its land dependent on engineered water management. Extreme rainfall, sea level rise, drought, and heat stress are increasingly pressing issues, especially in urban areas where concrete surfaces limit water absorption and amplify high temperatures. Dutch national and municipal governments have made climate adaptation a growing priority in recent years, embedding it into spatial planning and urban development agendas. At the national level, the Delta Programme provides long-term strategies and funding for water safety and climate resilience, while cities such as Amsterdam, Rotterdam, and Utrecht allocate dedicated budgets to reduce car traffic, create green roofs, improve biodiversity, and make neighbourhoods more flood-resilient (National Delta Programme 2025).

It is noteworthy that projects of this kind are funded directly by the Dutch government. While similar initiatives may exist elsewhere, they are more often supported by bottom-up organizations such as NGOs or community groups. In The Netherlands, both climate adaptation and creativity are supported at a governmental level. For example, the Creative Industries Fund NL is a national cultural fund for design, architecture, and digital culture that finances innovative design projects that address societal issues (Stimuleringsfonds 2025). The Netherlands has a cultural tradition of valuing design, innovation, and collective problem-solving, which shapes how climate challenges are addressed today.

Since the 1960s, architects and planners, such as N. John Habraken, have explored user-centred methods in urban development (Open Building 2025). These methodologies have evolved over time to become more dynamic forms of co-creation and bottom-up initiative. This transformation has been driven by growing recognition that resilience, particularly in the climate space, depends not only on large-scale infrastructure but also on the lived experiences, knowledge and engagement of residents.

Learning from Design

Design plays a vital role in shaping collaborative approaches to climate adaptation. Rather than working within fixed structures and rules that often define governmental processes, design emphasizes deep collaboration, experimentation and user-centred thinking. This presents opportunities for governments and design-driven initiatives to work together and complement each other. Through analysis, new intermediary roles emerged to bridge the gap between municipal/national government and residents to enable the translation of policy goals into local action. These roles highlight how design can act as a connector, aligning governmental ambitions with resident needs.

The urgency of climate adaptation demands approaches that are both technically sound and community-centred. Design methodologies can help support this balance by enabling dialogue, fostering trust, supporting shared ownership and facilitating action. Crucially, in these cases, resident participation is valued as the core goal and not a means to an end. This means shifting away from extractive engagement practices that risk participation fatigue toward methods that empower residents as active partners in shaping resilient neighbourhoods. In this way, design contributes not only to specific adaptation infrastructure but also to new frameworks of governance rooted in collaboration and inclusivity.

Case studies: Four Examples from The Netherlands

The following case studies explore different applications of design-driven resident engagement in climate-adaptation projects in The Netherlands. The cases differ in scale (municipal to national) and approach (methods of engagement). These examples can be used as inspiration on their own and to draw conclusions of learnings to take forward into new initiatives beyond the Dutch context.

Giving Residents a Say in Urban Development

The City of Amsterdam is continuously redesigning neighbourhoods to address climate change and infrastructure needs. In the eastern part of the city, parking spaces are being reduced to make way for green infrastructure that can help manage frequent flooding and minimize heat stress. This initiative is part of a broader climate adaptation strategy to make urban spaces more resilient, sustainable and enjoyable for residents.

To involve residents in the redesign process, the City of Amsterdam partnered with design research agency Stby (STBY 2025) to host a series of StreetLab sessions (KEMs 2025). These workshops provided an open, collaborative setting where residents could share their ideas, concerns and visions for the new green spaces. The approach reversed traditional roles: civil servants participated as listeners, while residents took the lead in telling their stories.

While the community welcomed the idea of more green space, a challenge quickly emerged: Who will maintain these areas over time, and how should responsibilities be shared between residents and the municipality? Without clear roles and resource allocation, that initial enthusiasm for new green spaces could fade and the vegetation could deteriorate.

The sessions revealed a strong willingness among some residents to take part in maintenance efforts. However, many felt unprepared, citing a lack of knowledge about when and how to care for plants, as well as limited access to the right tools and materials. Without involving residents in the re-design process, this new challenge and opportunity may not have emerged.

By bringing residents and policymakers together in this way, the project fostered mutual understanding and trust. The next steps involve developing support for residents to upkeep the new greenspace, such as accessible training and equipment needed for seasonal maintenance. This collaborative model is helping Amsterdam create greener neighbourhoods that are not only climate-ready but also co-owned by the people who live in them.

Image 1: Residents sit around a map of their neighbourhood at a StreetLab in Amsterdam East. Credit: Katy Barnard, Stby

Local Green Coaches Support the Community

In recent years, Amsterdam North has undergone major infrastructural developments. As investors continue to maximize profits per square metre of concrete, more of the green spaces that once defined this part of the city have disappeared. Many long-time residents have felt overwhelmed and dissatisfied with city policymakers, leading to protests over poor social conditions and the lack of meaningful involvement in shaping their neighbourhoods, a place that once resembled a village, with clean streets and abundant greenery. At the same time, the newly built housing has attracted newcomers, often younger, highly educated and politically-engaged citizens, who also desire clean, green spaces for themselves and their children.

With much needing to be repaired between residents and the city government, a new initiative emerged: Buurtgroen020 and their green coaches, supported by the Amsterdam city government (Buurtgroen020 2025). These are paid (expenses-covered) volunteers that live in the neighbourhood who have extensive knowledge of gardening as well as government procedures. They function as consultants on green initiatives in the neighbourhood. In times of eroding social cohesion, they serve as bridge-builders between residents and policymakers, guiding residents through formal procedures while keeping the council informed about local developments on the ground. Green coaches are always available to answer questions and provide advice on planning and planting. They participate in meetings with both residents and policymakers to ensure clear collaboration and communication.

A key example is the IJdok project, transforming a 400 m² paved square suffering from stormwater and heat issues into a communal garden. The green coach coordinated multiple residents' visions, encouraged participation, and led bike tours for policymakers to illustrate local challenges and opportunities. The project will soon proceed to landscaping and resident-led planting, supported by a fund for tools and locally sourced organic plants.

The success of the *Green Coach* programme is reflected not only in a greener living environment but also in the connections it fosters among residents who might never have met otherwise. Neighbours gather over tea, sharing their communal vision for their gardens, generating a strong sense of positive energy. Unsurprisingly, word spreads quickly, inspiring more residents to apply for communal green spaces in their own streets. Each completed project motivates the next, creating a momentum that unites neighbours around shared dreams and perspectives while also building resilience against climate change. The initiative has now been expanded to other parts of Amsterdam and holds promise for adaptation in other cities, thanks to its effectiveness and its focus on strengthening community at the local neighbourhood level.

Image 2: Residents in Amsterdam North work together to build a community garden. Credit: Inèz Schoorlemmer, Green Coach, Groenbuurt020

A National Competition for Less Concrete

Urban areas in The Netherlands are increasingly challenged by heat stress, flooding and declining biodiversity, consequences of the abundance of hard, impermeable surfaces like concrete and garden tiles. NK Tegelwippen, in English the 'National Tile-Wipping Competition' (NK Tegelwippen 2025), a national campaign organized by creative agency Frank Lee (Frank Lee 2025) and funded by the Dutch Government, is a creative response to this crisis.

Through a playful competition, NK Tegelwippen encourages the whole of The Netherlands to remove as many tiles as possible from their gardens, business parks, public squares, etc. and replace them with plants. Tiles are counted per municipality, competing against each other for the title of having the most 'wipped' tiles. Submissions from residents are verified by the platform, and the website tracks the progress of each location.

Since 2020, NK Tegelwippen has been an annual competition, and more than 17 million (and counting) tiles have been removed. That means over 300 football pitches of green space were added in The Netherlands. The competition element motivates residents to get involved with greening their surroundings. To help, many municipalities support residents with services like tile pick-up ('Tile Taxis') and free plants during the competition period.

Wageningen University and Research found that one tree cools as well as ten air conditioners (Van de Sande 2021). A green environment is also healthier and makes people happier. Yet, in the 32 largest municipalities in The Netherlands, half of the neighbourhoods are too paved, according to research by Natuur en Milieu, with less than 75m² of public green space per residential address (Penders 2024). For residents, a tiled garden seems easy to maintain, but greenery has many more advantages: trees, plants, and grass ensure better drainage of rainwater during increasingly frequent downpours and lower temperatures during increasingly hot summers.

NK Tegelwippen informs citizens, in a playful way, the benefits of having more green and less pavement. The visual materials for the national campaign created by Frank Lee appeal to both citizens and policymakers, promoting climate adaptation, biodiversity and urban beautification.

Image 3: Residents fill their new greenspace with plants after removing tiles in front of their house. Credit: Eva Braaksma and Frank Lee, NK Tegelwippen

Co-creating Green Rooftops

In a small country with a growing population, it is not always possible to create greenspace on the ground. Rooftops represent one of the largest untapped areas in urban environments, approximately 600 km² across The Netherlands. Rooftop Revolution aims to address pressing urban challenges such as heat stress, water management and biodiversity loss through the creation of multifunctional green rooftops (Rooftop Revolution 2025). Supported by municipalities, housing associations, housing corporations and entrepreneurs, they help meet climate goals by supporting residents in imagining and implementing green roofs in their communities.

Rooftop Revolution offers advisory support, access to subsidies, technical knowledge, project facilitation and community engagement. Through neighbourhood campaigns, they collaborate with local residents, municipalities and property owners to implement green roof projects that are both ecologically beneficial and socially inclusive. Local residents are delegated to champion green roofing projects happening in their area, with support and knowledge from Rooftop Revolution. These efforts not only enhance urban resilience but also foster a sense of community and shared responsibility. In the *Anne Frankwijk* initiative in Diemen, the organization assisted residents in transforming their rooftops into green spaces. This pilot project led to the establishment of six 'pioneers' who actively shared their experiences, encouraging broader participation and demonstrating the potential for widespread adoption.

Additionally, Rooftop Revolution organizes the Roof Cycling Days (Dakfietsdagen) to raise awareness about the potential of rooftops for sustainable urban development. Participants embark on guided bike tours across cities to visit existing green roofs, learning firsthand about their benefits and the processes involved in their creation. The tours often include stops at notable projects, such as De Dakakker in Rotterdam (DakAkker 2025), Europe's largest edible rooftop, and the Zoku Hotel in Amsterdam (Zoku Amsterdam 2025), which features a rooftop greenhouse and recreational space.

The core of this way of working is inspiring, educating and motivating people to take action in their own neighbourhoods to plant vegetation on flat roofs. Having a green thumb is not a requirement, but commitment and enthusiasm are. Working in this way, Rooftop Revolution deepens the energy that is already present in neighbourhoods for greater biodiversity, a cooler living environment and closer ties with the community.

Image 4: A group of residents lay down greenery on the roof of a home. Credit: Rooftop Revolution

Challenges to Overcome

All four of these examples show successful collaboration between residents and government, with the guidance of creative third-party partners connecting the two. Yet, significant challenges remain. Initiatives often take years from concept to execution, requiring sustained engagement to prevent fatigue and ensure residents feel their voices are heard. Collaboration between residents and government is crucial, but success depends on committed municipal staff and accessible platforms where both parties can participate on equal footing. Political and societal factors, such as shifting governmental priorities impacting budget allocation, climate denial and public frustration towards changes in their surroundings, can complicate the process. Demonstrating tangible outcomes, prioritizing knowledge transfer between initiatives and maintaining open communication are therefore essential to sustaining momentum and trust.

Discussion: New Roles and Responsibilities

As the case studies exhibit, engaging residents in climate adaptation initiatives requires creative new roles and responsibilities of third-party initiatives to bring together sustainable policy goals and resident needs. The following three roles are discussed further below: the bridge builder, the neighbour and the energizer. Additionally, new roles from the sides of the government and the residents themselves have emerged. This is primarily in the proposal of a new governance structure called the 'do-democracy', where residents can work bottom-up on greening efforts with the support of government resources (DoeDemocratie.nu 2025). These roles and responsibilities serve as lessons for other initiatives to consider when engaging with residents on climate related projects.

The Bridge-builder

One of the most critical roles in climate-adaptive urban development is that of the bridge-builder: someone or an organization who connects the needs and desires of residents with the resources and goals of governments and can direct the energy of those involved. This role was present in all four case studies. NKTegelwippen mobilizes residents through a campaign primarily inspired by national policy to increase water-resilience. Rooftop Revolution and Groenbuurt020 both work in neighbourhoods to make green initiatives happen, engaging neighbours and supporting them with a connection to municipal funds. Stby works as an external bridge, specialized in human-centred design that can foster conversation between residents and civil servants. Whether they are local leaders, civil servants, or external organizations, bridge-builders are passionate about participatory design and have knowledge of both the governmental and resident worlds. Their work is rooted in building trust, creating dialogue, and fostering collaboration across these perspectives.

In The Netherlands, national and local governments often have dedicated funding for climate adaptation. At the same time, residents are motivated to make their neighbourhoods greener and more liveable. At the core, their goals are aligned but the language

they use is different, and on top of that, the government resources often remain invisible or inaccessible to communities. This makes it difficult to find the connection. By translating technical goals into meaningful, accessible language, bridge-builders enable residents to take ownership of projects that not only improve quality of life but also strengthen resilience to climate impacts. In this way, abstract climate policies get turned into tangible neighbourhood transformations, ensuring that both governments and communities see their efforts reflected in a shared vision for a more resilient city. The work of the bridge-builder is even more impactful if they are an active resident of the neighbourhood themselves, which leads to the next role.

The Neighbour

The most effective resident engagement happens when the bridge-builders or other core stakeholders are embedded in the community and intimately familiar with the neighbourhood's residents and lived experiences. Government officials, whether at the city or national level, cannot fully grasp the nuances of every neighbourhood, from social dynamics to local priorities and everyday challenges. Local actors who live and/or work in these areas bring this essential knowledge. And with a design-focused mindset, these neighbours are well positioned to facilitate meaningful co-creation of sustainable initiatives. This is clearly demonstrated in how the Groenbuurt020 initiative is set up. The Amsterdam municipal government recognizes this strength, which is why local green coach volunteers live in the communities they serve. Rooftop Revolution also employs the neighbour role by getting local residents to champion new green roofing projects in each neighbourhood they start a project in. The neighbour's presence strengthens the connection between residents and the government climate-adaptation projects designed to improve their environment, ensuring that initiatives are both relevant and impactful.

Choosing to design such initiatives with on-the-ground ambassadors fosters deeper grassroots action and community ownership. They help mobilize neighbours, identify opportunities for improvement, and sustain long-term engagement. They see their collaborators at the grocery store, on the square or waiting by the bus. These consistent interactions enable even deeper trust and motivation to grow. By anchoring climate adaptation efforts in local knowledge and relationships, communities are empowered to take initiative. This approach not only makes interventions more effective but also builds social cohesion and a shared sense of responsibility for a resilient, thriving neighbourhood.

The Energizer

Without resident buy-in, community-based climate adaptation projects wouldn't be possible. The energizer role thrives on spreading enthusiasm, making abstract climate-adaptation goals relatable and encouraging residents to take initiative through playful and inspiring experiences. Both NK Tegelwippen and Rooftop Revolution exemplify this role well. NK Tegelwippen turns the process of replacing garden tiles with greenery into a fun, competitive national campaign, motivating citizens to take action through competing with neighbouring municipalities while demonstrating the environmental and social benefits of greening urban areas. Rooftop Revolution motivates residents to transform underutilized rooftops into green spaces by supporting neighbourhood pioneers to share their success stories and bringing curious residents on Roof Cycling Days to showcase thriving projects. In both cases, energizers bridge the gap between knowledge and implementation, inspiring residents to take the first step.

Energizers help foster a culture of collective action and shared responsibility. Here, design is used to share knowledge, support community action and provide infrastructure for success. Through continuous engagement, these actors not only motivate residents to act but also sustain long-term care and involvement in local initiatives. Rooftop Revolution's neighbourhood campaigns and NK Tegelwippen's national competition both create visible, shared achievements that reinforce participation and community pride. By providing encouragement, resources, and recognition, energizers enable residents to see tangible results from their contributions in a fun way. This motivation empowers communities to take ownership of their environment and inspire others to do so as well.

The 'Do-democracy'

The 'do-democracy' (or 'doe-democratie' in Dutch) model represents a transformative shift in governance, emphasizing active citizen participation in shaping their environments. In this approach, municipalities step back from direct control and instead provide residents with the tools, trust and resources necessary to initiate and implement change. Central to the success of the do-democracy model is the establishment of supportive infrastructures that facilitate citizen initiatives, including accessible policies, open communication channels, appropriate funding, needed education and trusted intermediaries who can guide residents through the processes. Projects like Stby's StreetLab approach, the Green Coach programme, NK Tegelwippen and Rooftop Revolution illustrate how resident-driven action can flourish when paired with these forms of support.

This model fosters a collaborative environment where citizens are empowered to take ownership of local issues, leading to more sustainable and contextually relevant solutions. Residents can take ownership of creating new greenspaces, maintaining communal gardens or greening rooftops, while municipalities provide the tools, expertise and infrastructure needed for success. Design plays a pivotal role in this collaborative model, helping translate ambitions into actionable steps, mediating knowledge transfer and facilitating community engagement. These efforts highlight the importance of fostering a culture of co-creation and mutual support. Climate adaptation initiatives must not only be technically feasible but also socially embedded, inclusive and beneficial. When residents are trusted and supported to act, they can drive meaningful, sustainable change that complements government goals, paving the way for more climate resilient and connected communities.

Conclusion: It's All About Relationships

At its core, meaningful resident engagement in climate-adaptive urban development is based on relationships. Between residents, governments and local experts, a foundation of trust, support, knowledge and connection is key. This work cannot be done alone. The government must put effort into fostering an open and collaborative relationship with residents, and residents also need to take ownership of their environment. This new relationship goes both ways and will take time to nurture. Local experts and third-party actors, as described in this paper, can be valuable assets to helping these relationships thrive through design. The goal is not just to support one-time projects, but to cultivate a long-term collaboration for climate resilience. These stories of do-democracy experimentation should not sit in a vacuum, but rather inspire and connect other initiatives to take action; each initiative is its own demonstration that change is possible. Without support, good projects remain local and isolated.

This makes it incredibly important to meet, share and advocate for collaborative climate action with residents. For example, Amsterdam Weerproof is a network of climate-adaptation initiatives that helps residents, professionals and public agencies work together to make the city resilient to extreme rainfall, heat, drought and flooding (Weerproof 2025). Its core idea is to shift how changes are made in the urban environment: rather than only reacting, Weerproof encourages everyone to take action at every level. The network hosts events, provides tools, makes connections between parties and shares success stories on their platform to inspire and connect others. But, smaller initiatives can also make a big difference. As part of London Climate Action Week 2025, Stby and Quicksand (Quicksand Design Studio 2025) brought together a group of practitioners working at the intersection of climate, policy, design, and community engagement to reflect on a critical gap: the meaningful participation of local communities and institutions in shaping and driving climate action (STBY 2025).

Looking Ahead

The path forward for how urban areas will adapt to climate change will be complicated, but as with everything in life, it's better done together than alone. The stories of rich resident engagement across varying climate-adaptive development projects in this paper shine an optimistic light on how a new future of working together in the city can look like. They serve as a starting point for others to learn and grow from. There are immense possibilities to expand on these ideas, for example creating space for collaboration with climate activists, artists or young people. Design as a mindset of empathy, co-creation and experimentation can continue to be a guiding post in inspiring new forms of working together, implementing new ideas and sharing them with the community.

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Toward a Dynamic Treatment-diagnosis System for Assessing Design Power in Cities

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Abstract

Design is increasingly recognized as a transformative force in urban governance, yet cities continue to lack rigorous frameworks to evaluate how design capacity evolves and influences systemic outcomes. This paper introduces the City Design Power Assessment system, a dynamic treatment-diagnosis framework built around two core toolkits: the City Design Power Index (CDPI) and the City Self-Appraisal. We trace the system's development through three phases: first, the creation of CDPI 1.0, grounded in an A–B–C framework (Antecedents, Behaviours, Consequences); second, the integration of the City Self-Appraisal to support qualitative stakeholder engagement; and third, the enhancement of feasibility and scalability via AI-assisted data pipelines. To demonstrate the system's analytical utility, we present a pilot empirical study using Cross-Lagged Panel Modeling (CLPM) with longitudinal data from 22 Taiwanese cities. The results reveal a time-lagged causal relationship: sustained cultural support predicts increased entrepreneurial vitality over a three-year period. These findings validate the CDPI's diagnostic logic and highlight the importance of long-term policy commitments in leveraging design as a strategic urban resource. The paper concludes by outlining future directions for cross-level analyses and potential international applications.

Keywords: AI-automation indicator data collection, city design power assessment system, longitudinal urban assessment, treatment-diagnosis framework.

1. Introduction

Cities are dynamic, multi-layered systems shaped by the interplay of infrastructure, institutions, social practices, and competing priorities. Within these complex systems, design has become an increasingly influential force, particularly in urban policymaking and planning. However, this growing influence raises pressing questions about how the impact of design can be systematically assessed. Despite widespread recognition of design's value, cities often lack the evaluative tools necessary to monitor how it is embedded within governance, policy, and innovation frameworks (Kaur and Garg 2019; Volk et al. 2022; Wolfram 2016). Although established urban indices such as the *Global Innovation Index*, the UN's *City Prosperity Index*, and the OECD's *Better Life Index* offer useful benchmarks for economic performance, quality of life, or infrastructure, they do not directly measure the strategic use of design across institutional levels. Likewise, design-focused indices like the *Design Value Index* or *UNESCO Creative Cities indicators* tend to highlight cultural outputs or achievements within specific sectors, but seldom assess how these efforts are integrated into broader governance systems or contribute to long-term urban transformation. This gap points to the need for an integrated framework that allows cities to track how design strategies, actions, and outcomes evolve over time and across levels of governance.

To address this need, we introduce the City Design Power Assessment system, a treatment-diagnosis framework developed to help cities evaluate their readiness to lead design-driven transformation. The system aims to facilitate long-term planning, align design initiatives with policy objectives, and foster institutional learning across sectors. Since its initial presentation at the 2023 WDO Research and Education Forum in Tokyo (Japan) (Shyhnan et al. 2023), the framework has undergone three phases of iterative development, guided by academic research, expert consultations, and collaboration with city stakeholders. This paper outlines these development phases and, in the methodological section, presents a pilot application of a time-sequential approach to illustrate the analytical potential of the CDPI.

2. Development Phases

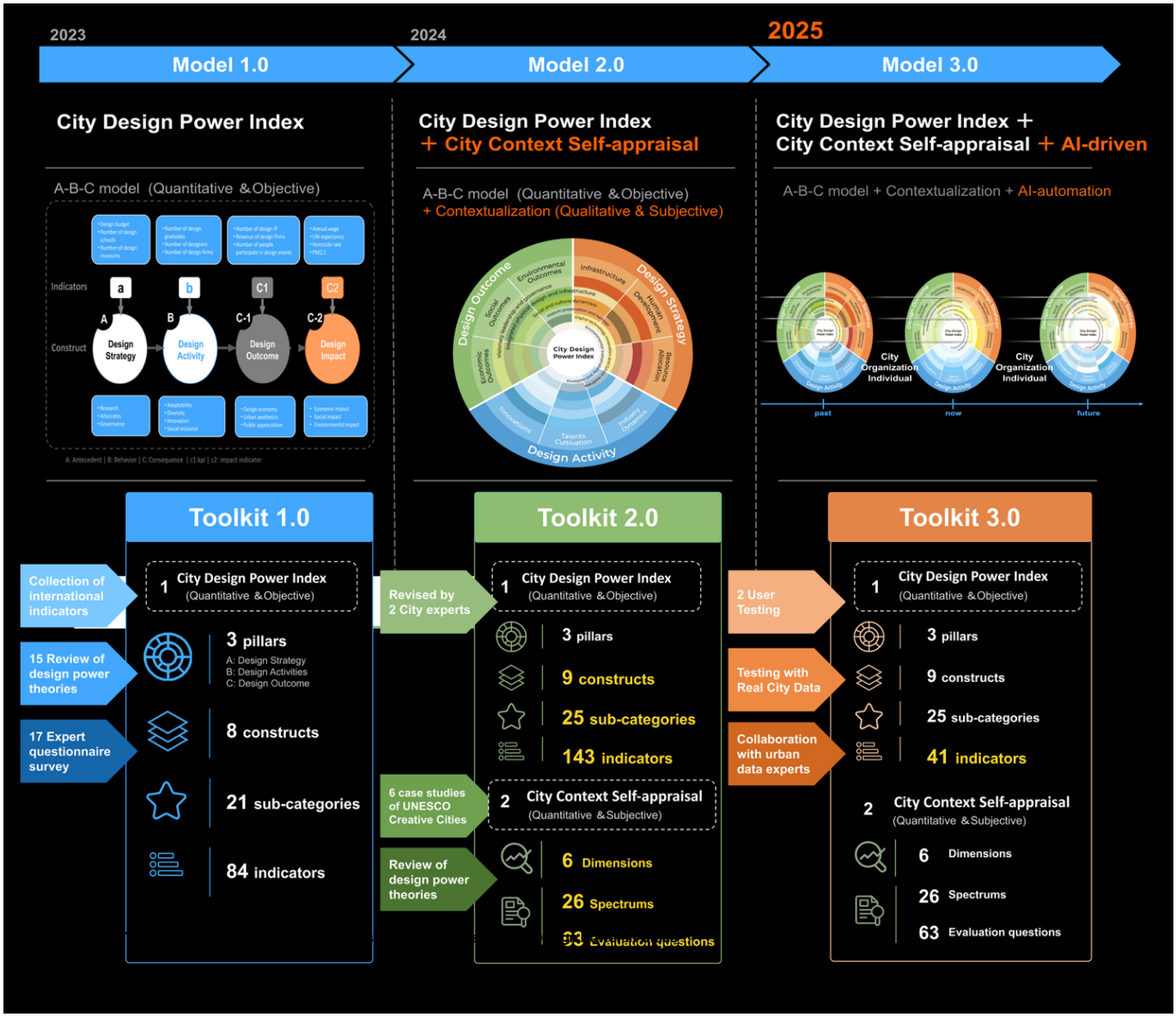

Figure 1: Multi-phase development of the City Design Power Assessment system.

2.1. Conceptual Foundations and Contextual Relevance

The City Design Power Assessment system has evolved over three years of iterative research, piloting, and expert feedback. Each phase has progressively refined the system's ability to assess how cities mobilize design as a strategic tool for systemic transformation. In its initial phase, we introduced the CDPI, built on a foundational A–B–C model that conceptualizes city design power through three interrelated pillars: Antecedents (Design Strategy), Behaviours (Design Activity), and Consequences (Design Outcomes). This model was developed through a multi-stage process involving international indicator reviews, expert consultations, and empirical validation using longitudinal data from 22 Taiwanese cities[1].

The resulting framework consisted of three pillars, nine constructs (e.g., financial support, industry dynamics, creative professionals), 21 sub-categories (e.g., physical infrastructure, industry competitiveness), and 84 indicators. To support data interpretation, we also developed two interactive visualization dashboards in collaboration with the MIT City Science Lab @ Taipei Tech: a radar chart showing performance across indicators, and a map view illustrating the spatial distribution of design-related assets across city districts (see Figures 2 and 3). These tools were designed to help local policymakers monitor the distribution of design power and track its evolution over time. Both dashboards, initially created in the first phase, were updated in the latest version of the system to reflect refined indicators and an improved data structure.

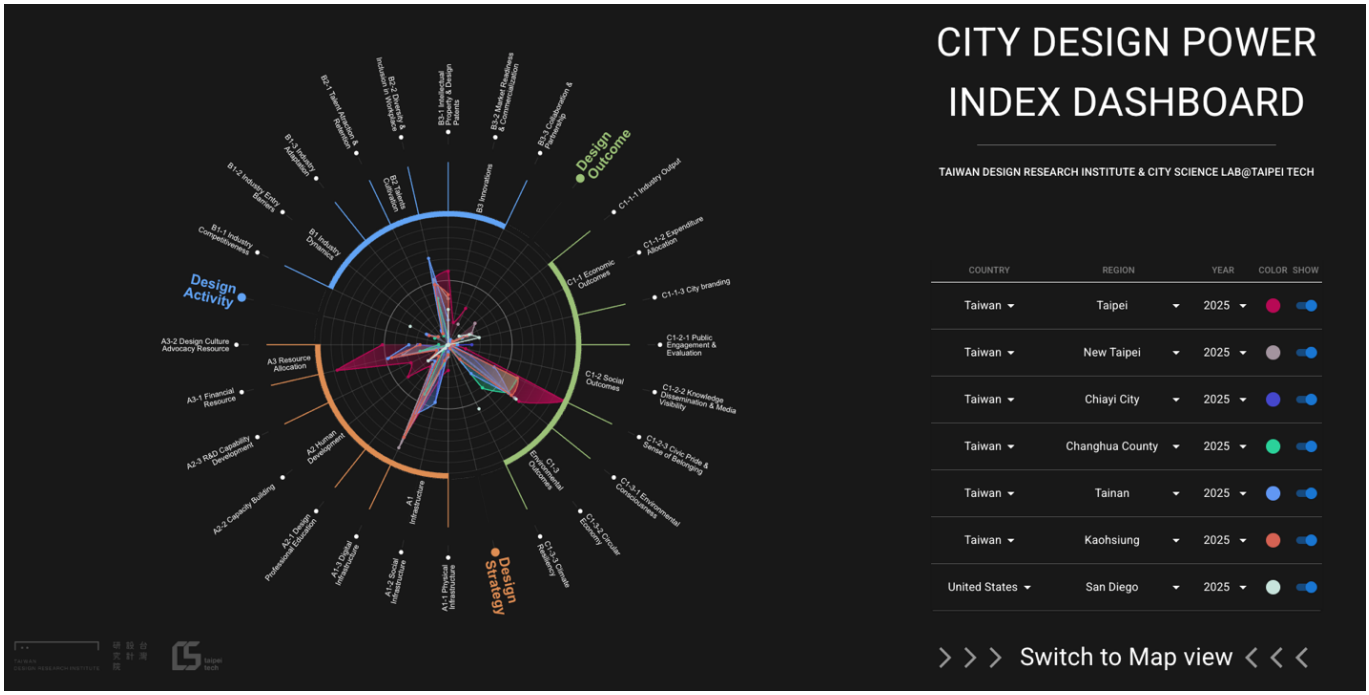

Figure 2: Radar chart dashboard (updated version).

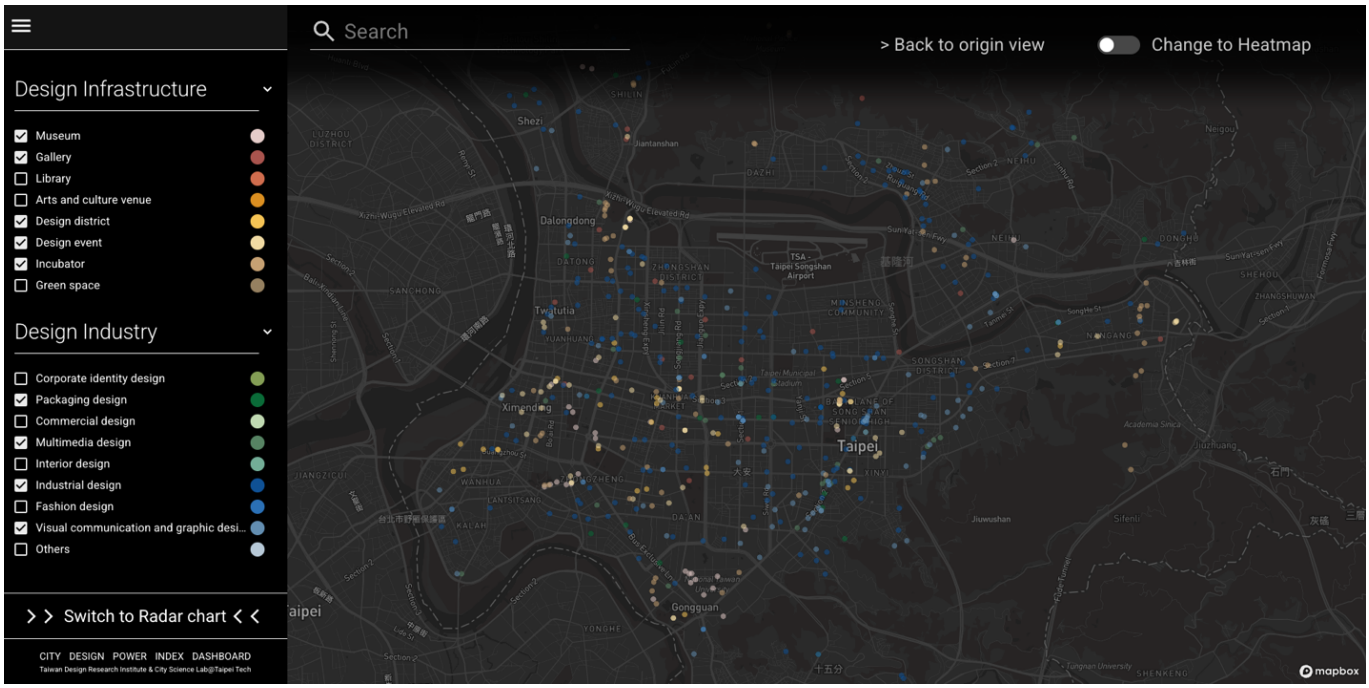

Figure 3: Map view dashboard (updated version).

1 For a detailed account of the methodological development of CDPI 1.0, see: Shyhnan, Liou, Chang Chi-Yi, Chen Yu-Chen, Chen Junyu, Hsieh Ying-Yi, Liu Tu-Chung, and Kuo Tang-Ling. 2023. *"Developing City Design Power Index Model."* WDO Research and Education Forum 2023, Tokyo.

However, findings from this initial phase revealed the limitations of applying a standardized model across diverse urban contexts. For instance, while Bandung exemplifies informal, community-driven creative ecosystems, Singapore reflects a more institutionalized and state-led approach to cultural and design development. These contextual differences affect how indicators such as citizen engagement in cultural production or public access to creative venues are interpreted and measured. In response, we identified contextualization as a key area for further development within the City Design Power Assessment system, recognizing that cities operate under distinct political, cultural, and socioeconomic conditions (Moghadam 2024; Oleksandrivna 2024). During the second phase, we collaborated with two senior urban planning experts who had led major design and planning projects across Taiwan, China, and Singapore to revise and expand the original CDPI indicator set. This effort resulted in the addition of 59 new indicators and the creation of a City Self-Assessment Questionnaire aimed at capturing context-sensitive, qualitative dimensions of design power. Drawing on comparative case studies from six UNESCO Creative Cities Network (UCCN) members, such as Helsinki (Finland), Kobe (Japan), Shenzhen (China), Wuhan (China), Singapore (Singapore), and Bandung (Indonesia) (UNESCO 2025), we identified six key dimensions of contextual influence: a) visionary leadership and governance, b) integrated physical design infrastructure, c) social and cultural dynamism, d) historic preservation and heritage, e) digital technology innovation and future readiness, and f) environmental sustainability and resilience. These dimensions were further operationalized through 26 sub-dimensions and 63 diagnostic questions (see Figure 4).

2.2. Feasibility Refinement and AI-driven Application

Throughout the first two development phases, our team encountered several practical challenges in operationalizing the framework and collecting indicator data. Two main issues emerged: (1) unclear operational definitions for many indicators and (2) limited feasibility of data collection due to constraints in time, resources, and interdepartmental coordination. To address these challenges systematically, we conducted multiple rounds of usability testing with professionals involved in city-related projects within our organization. This process revealed six recurring issues within the CDPI indicators: (a) ambiguous definitions and scope, (b) difficulty calculating values, (c) questionable validity relative to the CDPI framework, (d) redundancy or overlap with other indicators, (e) low feasibility of data collection, and (f) unclear measurement units or data sources. These findings informed a comprehensive revision process in which we refined all operational definitions and streamlined the indicator framework to improve clarity and usability.

As a result, the updated CDPI framework now includes a reduced set of 41 core indicators, each accompanied by suggested measurement methods and data input guidelines (see Figure 5). For example, the indicator “number of multifunctional open spaces dedicated to cultural and creative industries” now includes both an operational definition (e.g., public or private spaces with “history,” “culture,” or “innovation” as permanent themes) and recommended data collection procedures (e.g. consulting city government open data or searching Google Maps using specific keywords). The refined version has received positive feedback for its improved practicality and clarity.

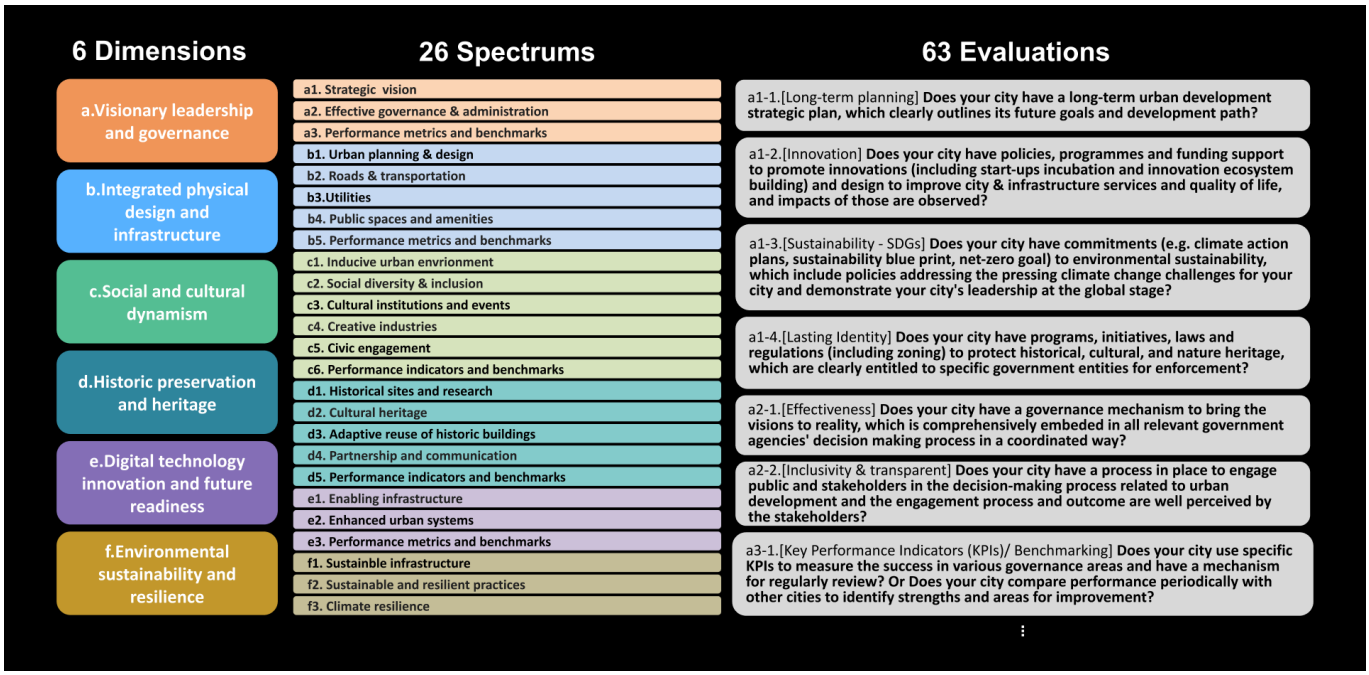

Figure 4: City context self-appraisal tool.

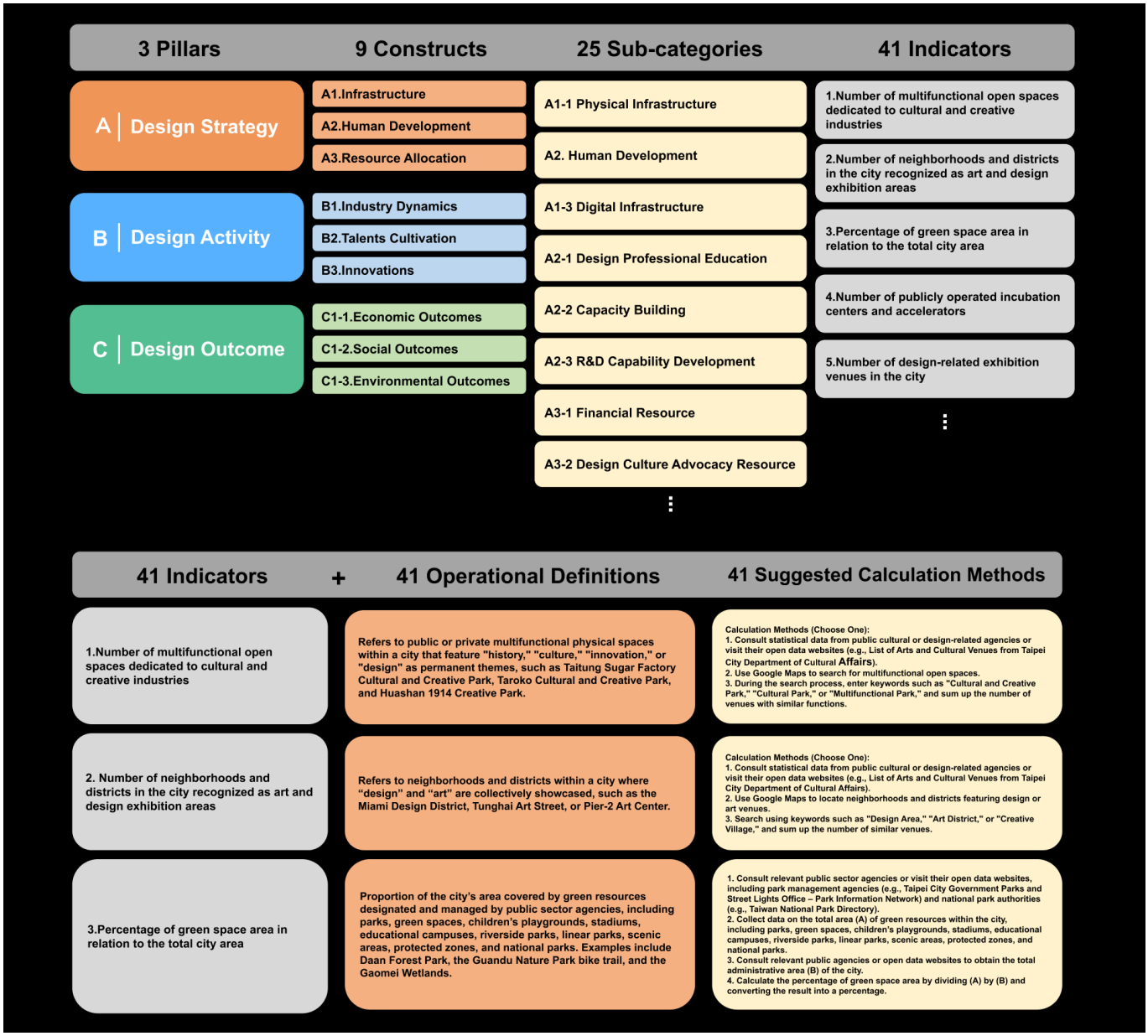

Figure 5: CDPI most recent revised framework.

A second major challenge involved data collection itself. During implementation, we found that data relevant to CDPI was often not prioritized by government agencies, lacked dedicated budgetary resources, and was not embedded in key performance indicators (KPIs). Additionally, related datasets were scattered across departments, lacked standardization, and varied widely in format and completeness. These barriers led to inconsistent results and limited the framework's applicability across different cities. To address these issues, we piloted the integration of automated and AI-supported data collection methods. In collaboration with the City Science Lab of MIT@Taipei, we tested AI-enhanced methods for data collection in six Taiwanese cities; Taipei, New Taipei, Chiayi, Tainan, Changhua, and Kaohsiung, with plans to expand to all 22 counties and cities across Taiwan in the coming year. The indicator framework was further refined to maximize compatibility with open-access data sources, reducing the number of indicators requiring manual collection to only four. Appendix 1 details the technical approaches used for data acquisition, outlining five categories of automation and their operational logic.

3. Methods

In addition to refining the CDPI framework for practical application, we explored its empirical validation using longitudinal data analysis. To this end, we conducted a pilot study employing Cross-Lagged Panel Modeling (CLPM) with time-series data from 22 Taiwanese cities. This pilot served two primary purposes: (1) to assess the analytical feasibility of applying CDPI as a dynamic, longitudinal tool, and (2) to generate preliminary evidence of potential causal relationships among its core dimensions. The subsections below outline the analytical rationale, dataset, and modeling procedures used in this pilot study.

3.1. Analytical Method

The CDPI framework is conceptually informed by a multilevel perspective that considers how national, organizational, and individual-level interactions influence a city's capacity to implement and sustain transformative design strategies. A city's success depends not only on municipal leadership but also on enabling national policies, inter-agency coordination, and the engagement of design communities and stakeholders (Pumain et al. 2015; Zientara, Zamojska, and Cirella 2020; Zürn 2020). Based on this perspective, we employed a cross-level, time-sequential approach using Cross-Lagged Panel Modeling (CLPM), a type of Structural Equation Modeling (SEM) widely used to

examine causal relationships in longitudinal data (Heise 1970). With at least two waves of data, CLPM estimates the relationship between a predictor at Time 1 and an outcome at Time 2 while controlling for the outcome's prior value. In other words, if variable X at Time 1 (T1) significantly predicts variable Y at Time 2 (T2), while controlling for Y at T1, then X is considered to potentially 'cause' Y.

We applied CLPM to examine whether Antecedents (A) influence Behaviours (B), and whether Behaviours subsequently lead to Consequences (C) over time. This approach enables the identification of time-lagged effects. For instance, whether investments in design strategies in one period led to increased design activity or measurable outcomes in subsequent periods. It also allows for the exploration of direct and indirect causal pathways among the ABC dimensions, offering deeper insight into the structural dynamics of design power over time.

3.2. Data

We used longitudinal data from 22 counties and cities in Taiwan spanning the years 2010 to 2022. For the purposes of CLPM, the 13-year period was aggregated into four-time intervals: T1 = 2010–2013, T2 = 2014–2016, T3 = 2017–2019, and T4 = 2020–2022. This yielded a panel dataset of 88 observations (22 cities × 4-time intervals), with each observation representing a city's indicator score for a specific construct within a given period. Data were manually collected from public sources including government portals, official statistical dashboards, and municipal reports.

3.3. Procedures

The pilot analysis included ten constructs: nine from the original CDPI 1.0 framework and one additional construct from CommonWealth Magazine's Urban Competitiveness Index. These constructs span CDPI's three core dimensions: Antecedents, Behaviours, and Consequences, and cover domains such as financial support, industry dynamics, economic outcomes, and city-level happiness. To prepare the dataset for longitudinal modeling, we used a time-series design covering the full 2010–2022 period, resulting in 286 total observations (22 cities × 13 years). Missing values were addressed through statistical imputation. We then applied Principal Component Analysis (PCA) to standardize and consolidate indicator-level data into construct-level scores. These steps produced a consistent and comparable set of longitudinal data across all ten constructs included in the analysis.

Because CLPM compares two constructs at a time, it requires one to be designated as the predictor (e.g., an Antecedent) and the other as the target (e.g., a Behaviour or Consequence). To identify meaningful pairings for causal modeling, we evaluated all 100 possible combinations of the ten constructs (10 × 10) and applied an exploratory trend-matching strategy using Microsoft Power BI dashboards. These dashboards allowed for visual inspection of construct trajectories across the 2010–2022 period for all 22 cities and counties (see Figure 6). Construct pairs showing similar temporal patterns, such as parallel upward or downward trends, were flagged as candidates for modeling.

Based on this screening, a focused set of construct pairs was selected for CLPM analysis. Among these, the pairing of Cultural Support (A3) as the predictor and Entrepreneurial Vitality (B1) as the target demonstrated a statistically significant cross-lagged effect. Model estimation was conducted using SPSS AMOS with maximum likelihood estimation. The final CLPM model included both autoregressive paths, which capture the temporal stability of each construct, and cross-lagged paths, which test the directional influence of one construct on the other over time. This enabled an assessment of whether higher levels of Cultural Support in one time period predicted increased Entrepreneurial Vitality in subsequent periods, beyond the influence of each construct's own continuity.

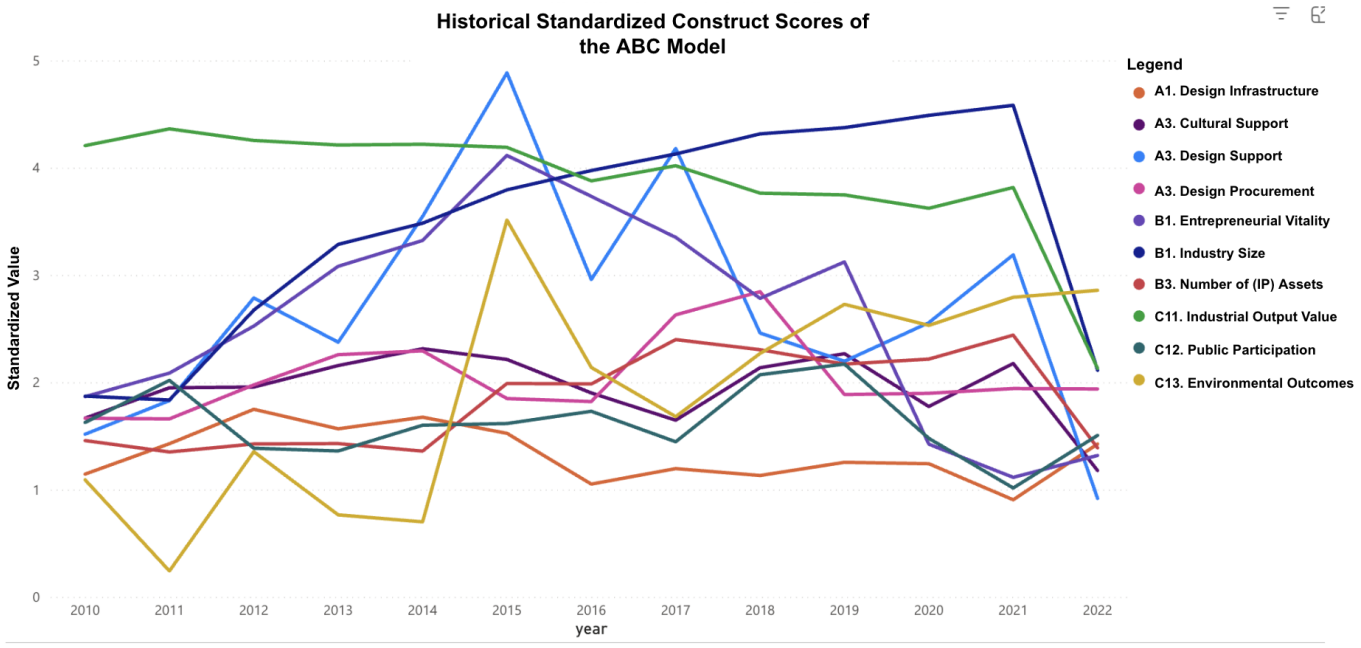

Figure 6: Microsoft Power BI dashboard.

4. Results

A four-wave CLPM was used to examine the time-lagged influence of Cultural Support (A3) on Entrepreneurial Vitality (B1). This model tested both autoregressive paths, which measure the temporal stability of each construct over time, and cross-lagged paths, which test whether one construct predicts another at a later time span while accounting for the stability of both variables. The results confirmed strong temporal consistency across waves for both constructs. Cultural Support showed significant autoregressive effects from T1 to T2 (β = 1.330, p < .001), T2 to T3 (β = 0.902, p < .001), and T3 to T4 (β = 0.888, p < .001). Similarly, Entrepreneurial Vitality exhibited strong stability over time, with significant autoregressive paths from T1 to T2 (β = 0.543, p < .010), T2 to T3 (β = 0.806, p < .001), and T3 to T4 (β = 0.613, p < .001). These results suggest that both constructs are internally consistent and evolve predictably over time.

More critically, the cross-lagged paths provide insight into how strategic cultural investments may influence subsequent entrepreneurial activity. Although Cultural Support at T1 did not significantly predict Entrepreneurial Vitality at T2 (β = 0.401, p = .060), the effect approached significance. In later waves, the influence became statistically significant: T2 Cultural Support predicted T3 Entrepreneurial Vitality (β = 0.211, p = .018), and T3 Cultural Support predicted T4 Entrepreneurial Vitality (β = 0.396, p = .032). These findings point to a delayed but consistent positive effect of cultural support; such as investments in public creative spaces, community programs, or cultural policy, on the vitality of the entrepreneurial ecosystem. Notably, no significant reverse cross-lagged effects were found from Entrepreneurial Vitality to Cultural Support. This suggests a unidirectional influence, consistent with the theoretical premise of the CDPI framework, in which strategic antecedents drive behavioural outcomes over time.

This analysis provides preliminary empirical evidence that cultural development policy plays a foundational role in fostering entrepreneurial capacity. However, the effects are not immediate, they accumulate and manifest over a multi-year period. This highlights the importance of long-term cultural planning and sustained investment. Based on the observed lag structure, we recommend that cultural support policies be designed with at least a three-year implementation horizon, to allow sufficient time for entrepreneurial outcomes to emerge meaningfully.

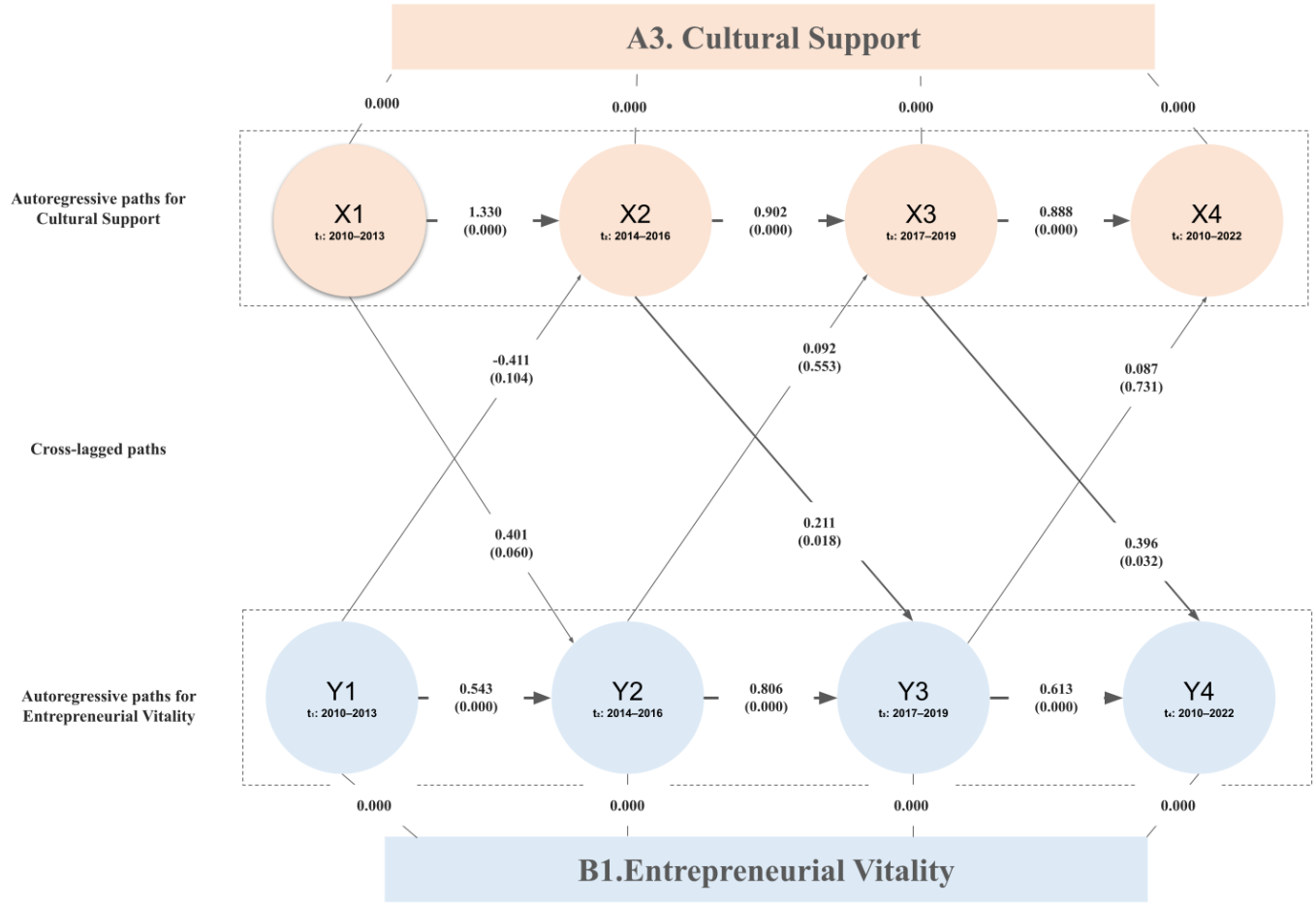

Figure 7: CLPM of Cultural Support (A3) and Entrepreneurial Vitality (B1).

5. Discussion

5.1. Findings and Implications

The results of the CLPM suggest a potential causal relationship within the CDPI framework, indicating that sustained cultural support may foster greater entrepreneurial vitality over time. The significant autoregressive paths observed for both *Cultural Support (A3)* and *Entrepreneurial Vitality (B1)* across all time intervals reveal strong temporal stability and internal coherence. This finding aligns with theories of accumulative capacity building in urban systems (Batty 2013), which propose that cities evolve through positive feedback loops, where prior advantages, such as policy investments or institutional networks, reinforce themselves over time. Within this framework, urban systems exhibit a degree of inertia, adapting gradually through structural mechanisms rather than undergoing abrupt change.

This theoretical lens helps explain the persistence of cultural and entrepreneurial indicators across Taiwanese cities. In Tainan, for instance, long-standing cultural policies emphasizing heritage preservation and creative placemaking have supported ongoing investment in cultural infrastructure, including the revitalization of historical sites and the development of public creative spaces. These initiatives have coincided with steady growth in creative entrepreneurship, reflected in the rise of local design studios and participation in cultural events[2]. Similarly, in Taipei, the Department of Cultural Affairs, established in 1999, has institutionalized public arts programs and the transformation of heritage zones into creative hubs, such as the Songshan Cultural and Creative Park. National programmes also demonstrate this stability. The Ministry of Economic Affairs' *Design Movement in Commercial Districts* initiative, implemented in cities including Changhua, Tainan, and Kaohsiung, integrates aesthetic planning and service design into commercial area revitalization[3]. By emphasizing co-creation among local governments, district organizations, and design teams, the program enhances public spaces, improves service experiences, and introduces design-driven guidance mechanisms that support tourism, cultural visibility, and local entrepreneurship. Such cross-sector collaboration illustrates how sustained cultural planning can activate city-level entrepreneurial ecosystems.

More importantly, the cross-lagged results indicate a statistically significant, time-lagged influence of Cultural Support on Entrepreneurial Vitality, particularly at the three-year interval. This supports the City Design Power Assessment model, in which antecedents (A) drive behaviours (B) over time. The observed lag aligns with research in creative economy policy and urban development, which suggests that the effects of cultural interventions often accumulate gradually through the development of social capital, trust networks, and shared meaning (Menger 2014; Throsby 2001). These findings carry significant implications for public policy. First, they challenge the assumption that short-term cultural programmes can meaningfully stimulate entrepreneurial change. The evidence points to a minimum three-year horizon for cultural support policies to produce measurable outcomes. This is particularly relevant for cities like Kaohsiung, where large-scale cultural investments, such as the Asia New Bay Area and the Pier-2 Art Centre, require long-term commitment to achieve their full entrepreneurial impact.

Second, the results align with the growing consensus in urban innovation research that cultural vitality serves as a catalyst for entrepreneurial ecosystems, particularly in cities undergoing creative transitions or economic restructuring (Evans 2009; Florida 2019; Pratt and Hutton 2013). Among the 22 Taiwanese counties and cities examined, governance models, resource constraints, and policy priorities vary considerably. Yet the CLPM results suggest that, regardless of institutional context, sustained cultural investment consistently correlates with enhanced entrepreneurial vitality over time. This underscores the strategic importance of cultural policy as a lever for building long-term innovation capacity and economic resilience.

5.2. Limitations and Future Research

While these results provide promising validation of the diagnostic logic underlying the City Design Power Assessment, it is important to acknowledge the limitations of the current pilot analysis. The CLPM was applied to a subset of constructs from the CDPI 1.0 framework and relied solely on open public-sector data, which varied in quality, completeness, and temporal coverage across cities. Consequently, the findings should be viewed as preliminary, yet meaningful, demonstrations of CDPI's analytical potential, rather than definitive empirical validation. To address these limitations, the City Design Power Assessment system has prioritized the development of a more robust and scalable data infrastructure, introducing two major advancements: (1) a comprehensive refinement of the indicator framework's feasibility, and (2) the piloting of AI-assisted data collection methods. These enhancements directly respond to the challenges identified in the pilot study; namely fragmented data sources, inconsistent formats, and the labour-intensive nature of manual data compilation.

Beyond these technical improvements, future research could employ Multi-group Structural Equation Modeling (MGSEM) to strengthen the validation of the City Design Power Assessment. Unlike CLPM, which can test only two constructs at a time, MGSEM enables the simultaneous comparison of multiple subsets, making it especially valuable as the dataset expands. As the City Design Power Assessment system continues to evolve through broader adoption, refinement, and expanded application, its growing dataset will support more sophisticated modeling of design governance dynamics. A promising example of this evolution is our ongoing international collaboration with the UC San Diego Design Lab (UCSD), which is currently piloting both the self-assessment and CDPI tools in San Diego (USA). This partnership is identifying key feasibility considerations for applying the system beyond Taiwan, including stakeholder engagement, institutional alignment, and clarity in tool interpretation. Insights from this work are informing the next phase of development. Building on the San Diego experience, future development phases aim to expand international pilot studies to further evaluate the feasibility, adaptability, and value of the City Design Power Assessment system across diverse governance contexts.

6. Conclusion

This paper presents the City Design Power Assessment system as a dynamic, multi-phase framework for diagnosing and enhancing a city's ability to leverage design as a strategic tool. Over three phases of development, the system has evolved into a practical and implementable approach. From its foundational A–B–C model to its latest AI-enabled data infrastructure, the City Design Power Assessment aims to directly address the challenges of operationalizing design governance across diverse urban contexts. Empirical analysis using CLPM provides preliminary evidence supporting the diagnostic validity of the CDPI tool, revealing a significant, time-lagged influence of Cultural Support on Entrepreneurial Vitality. This finding underscores the importance of sustained cultural investment as a driver of urban innovation and entrepreneurial growth. At the same time, the paper acknowledges limitations related to data quality and coverage. It also outlines how the City Design Power Assessment is actively addressing these issues through improved indicator design and the implementation of automated data pipelines.

2 The 2024 Taiwan Design Expo returned to Tainan for the fifth time and drew over 4.2 million visitors over the 16-day exhibition. Source: https://www.tdri.org.tw/en/news/463
3 Design Movement in Commercial Districts. Source: https://reurl.cc/LnK7Vx

Appendix 1: Overview of AI-driven and Automated Data Collection Methods for CDPI 3.0

Automation Method	Data Acquisition Characteristics	Number of Indicators	Example
API: Structured APIs are used to retrieve pre-formatted datasets directly from official open-data platforms. Data is accessed using specific URL parameters, parsed into structured formats (e.g., JSON), and imported into PostgreSQL for processing.	— Public access via API endpoint — Structured (JSON, CSV) — Minimal need for calculation	2	**Indicator:** percentage of green space area relative to total city area. **Data Source:** MIT City Science Lab @Taipei PostgreSQL Spatial Database. **API Query Configuration:** — **Table A:** geometry.boundary_city provides the total land area for each city/county. — **Table B:** geometry.af_nlsc_landuse_property contains land use classifications. The indicator filters records where code = 702, corresponding to "parks, green spaces, and public squares." — **Geographic Scope:** Taipei City, New Taipei City, Changhua County, Chiayi City, Tainan City, and Kaohsiung City. **Data Processing Logic:** — **Step 1:** Extract geometry-based area for land classified as green space (Code 702) per city from Table B. — **Step 2:** Retrieve total land area for each corresponding city from Table A. — **Step 3:** Compute the indicator value: percentage of Green Space = (Green Space Area / Total City Area) × 100.
Single-page Web Crawler: Web crawlers are written in Python to retrieve tabular or structured data from single-page public websites with a static DOM-Document Object Model structure. Data is parsed via HTML tags, then exported to spreadsheets for processing.	— Publicly accessible — Static page structure (no pagination) — Access to structured data without API	6	**Indicator:** Net industrial growth rate of the city **Data Source:** Open-source statistical portal from the Ministry of Economic Affairs (MOEA), Taiwan **Data Criteria for Extraction:** — **Tables A:** Number of existing registered companies. — **Table B:** Number of newly established companies registered. — **Table C:** Number of companies dissolved, revoked, and annulled. — **Geographic Scope:** Taipei City, New Taipei City, Changhua County, Chiayi City, Tainan City, Kaohsiung City. **Data Processing Logic:** — **Step 1:** A Python-based single-page crawler was deployed to extract relevant values from Table A, B, and C. — **Step 2:** The script identifies and parses the target table elements using attributes such as HTML class, ID, or tag structure. — **Step 3:** Compute the indicator value: (Newly registered companies (B) - Revoked companies (C)) / Total number of registered companies (A) x 100.
Multi-layered Crawler: Used for websites with complex layouts, pagination, or dynamic content. Crawlers simulate user behavior (e.g., clicking through categories, navigating filters). Data is collected from multiple sub-pages and merged.	— Public but non-static — Pagination or multi-view navigation — Requires simulation of user action — HTML structure inconsistent across pages	22	**Indicator:** Number of design-related departments or institutes in universities and colleges within the city. **Data Source:** uNews Taiwan (大學問) "University Department" search portal, filtered by the "Architecture and Design" category. **Data Criteria for Extraction:** — **Disciplinary Cluster:** "Architecture and Design" — **Geographic Scope:** Taipei City, New Taipei City, Changhua County, Chiayi City, Tainan City, Kaohsiung City **Data Processing Logic:** — **Step 1:** The crawler iteratively navigates across multiple pagination layers to access all entries listed under the "Architecture and Design" category. — **Step 2:** For each department, the script extracts metadata tags corresponding to location, discipline cluster, and institutional affiliation. — **Step 3:** The crawler filters departments based on city/county match (e.g., Taipei City, Kaohsiung City). — **Step 4:** The final indicator is computed as the total count of qualifying departments or institutes per city.

Automation Method	Data Acquisition Characteristics	Number of Indicators	Example
AI synthesizer: Uses pre-filtered structured datasets (e.g., Google Maps) and combines them with keyword filtering, classification rules, and AI-based natural language processing (NLP) for categorization.	– Structured input with embedded text (e.g., names, descriptions) – Requires semantic labeling – Rule-augmented NLP model for classification – Not purely statistical	3	**Indicator:** Number of multifunctional open spaces dedicated to cultural and creative industries within the city. **Data Source:** Google Maps **Data Criteria for Extraction:** – **Google Maps Place Types:** within the "Culture" category (e.g., art_gallery, museum, theater, art_studio, etc.) – **Geographic Scope:** Taipei City, New Taipei City, Changhua County, Chiayi City, Tainan City, Kaohsiung City. **Data Processing Logic:** – **Step 1:** A Python script extracts a comprehensive list of Points of Interest (PoIs) from Google Maps search results using predefined Place Type keywords. – **Step 2:** The full PoI list is evaluated by a language model, which assesses each entry based on its metadata (e.g., name, category, description) to determine alignment with the indicator's operational definition. – **Step 2:** The AI filters the list and returns only those PoIs that meet the criteria, which are then counted to generate the final indicator value.

AI crawler and synthesizer:
Information sources are scattered on public domains and need dynamic workflows. Set up analysis tasks for multi-level searching and synthesis on the open web. Use keywords to search a massive number of webpages, and AI analyzes the webpage content.
	– Unstructured or semi-structured sources
	– Scattered data across websites, news, and event listings
	– AI agent must reason and synthesize from multiple steps
		4	**Indicator:** Number of design events that have been continuously held for five years.
			
			Data Source: Internet search module via Tavily (an AI-compatible search engine).
			
			Data Processing Logic:
			– **Design Event Discovery AI Agent:**
			  – **Input:** Feed the agent with a set of keywords that define the scope of a "design event.".
			  – **Task:** Uses Tavily to search across the web for events that match the keyword criteria.
			  – **Output:** An structuralized list with the name of the events.
			
			– **Design Event Detail AI Agent:**
			  – **Input:** Takes the list of identified events from the previous agent.
			  – **Task:** Performs a second round of targeted searches to retrieve key metadata, such as the years the event was held and attendance numbers.
			  – **Output:** A structured dataset containing event names, annual occurrences, and (when available) the number of attendees.

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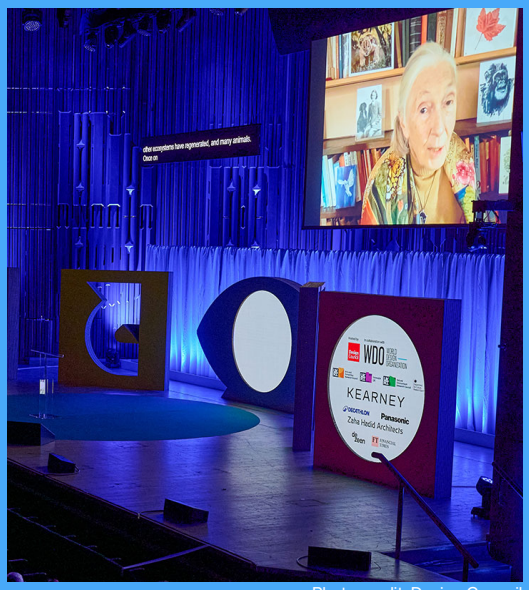

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