

Systemic Futures: Integrating Critical Speculation and Systemic Design Pragmatism

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ABSTRACT

Speculative and systemic design are both used by HCI researchers to engage in complex sociotechnical change. However, they are rarely integrated in ways that make their complementary strengths explicit. This paper introduces **Systemic Futures Dialogue**, a design approach that interleaves speculative and systemic design methods across micro-macro and present-future dimensions. We report on an 18-month case study with the Architecture, Engineering, and Construction (AEC) industry, that applied a mixture of methods used in both design disciplines. These included semi-structured interviews, systems mapping, future-based scenarios, speculative probes, and participatory reflection. The resulting design approach generates grounded futures by connecting macro-level system dynamics with micro-level speculative critique, identifying tensions between present-day solutions and desired futures. The final Systemic Futures Dialogue contributes methodological guidance for conducting critical, participatory design work within a sociotechnical system.

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CCS CONCEPTS

• **Human-centered computing** → **Interaction design process and methods; Interaction design theory, concepts and paradigms; Collaborative and social computing design and evaluation methods.**

KEYWORDS

Speculative Design; Systemic Design; Mixed Methods; Micro-Macro analysis; Present-Future analysis

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1 INTRODUCTION

The deliberate movement away from solutionism in speculative design, toward designer-led critique [21], stands in contrast with the participatory and pragmatic orientation of systemic design [32]. These different purposes make it challenging to apply both approaches in parallel; while speculative design opts for critique and reflection, systemic design instead aims to find opportunities for change. In this paper we demonstrate how the orchestration of these approaches can be useful to structure a movement between micro and macro perspectives of a sociotechnical system, whilst identifying design tensions between systemic change and long-term desirable futures.

Although speculative design and systemic design have important differences, their methods and foci could be applied in complementary ways, such that the strengths of one address the weaknesses of the other. Speculative design, while powerful for critiquing dominant assumptions and envisioning alternative futures, has been criticised for its designer-led orientation, which privileges expert voices and limits broader participation in imagining futures [43, 51]. While recent efforts aim to democratise this process [24], speculative design can meet opposition from the pragmatics of corporate objectives, and participants may find it difficult to engage in futures thinking without specialised training [24, 51]. Instead, we believe it is possible to embed designer-led speculation in systemic design activities that engage sociotechnical systems in participatory ways [31]. Meanwhile, speculative design can also address critiques that systemic design tends to remain at the level of policy or organisational design, overlooking the role of technology plays in systemic change [10].

However, to our knowledge no HCI research has examined how systemic and speculative design can be intentionally brought together. We therefore aim to articulate the challenges and opportunities that arise from combining methods from both disciplines. We examine the integration of these different methods by presenting a case study in which we designed technology interventions aimed at improving Architecture, Engineering, and Construction (AEC) sociotechnical systems. By sociotechnical system, we mean social systems (e.g. a group of people from different organisations collaboratively designing and constructing a building) that use technologies to assist in the organisation of activities (e.g. using cloud computing to share architectural files between organisations) [6].

From this case study, we extract and present the **Systemic Futures Dialogue** (Figure 1), developed in collaboration with AEC industry representatives. This structured orchestration acts as a guide for designers to balance the different epistemic purposes of speculative and systemic design, helping them to 1) ground speculative design in identified trends within a sociotechnical system, 2) structure participatory speculation, and 3) identify design tensions between planned systemic solutions and desirable technological futures. Overall, this paper makes the following contributions:

- The **Systemic Futures Dialogue**, a structured orchestration that integrates the strengths of speculative design and systemic design, showing how this integration can be reliably used by designers.
- An empirical study with participants from the Architecture, Engineering and Construction industry that provides a **clear illustration** of the Systemic Futures Dialogue in a **real-world context**.
- **Systemic Futures Tensions**, a novel epistemic contribution that results from combining systemic and speculative design using the Systemic Futures Dialogue. This conceptualisation of systemic change tensions generates opportunities to critically reflect on whether sociotechnical change might reinforce existing behaviours or realise a collectively desirable future.

Through these contributions, we offer a reproducible approach for researchers to collaboratively examine how technological interventions may impact a social system. In the long term, we hope this

work enables more reflexive design practices that question whether technological interventions support or hinder collectively desired futures.

2 RELATED WORK

2.1 Systemic Design and its Application in HCI

Systemic design is an emerging practice that aims to address complex social challenges by identifying opportunities for change [32]. As outlined in the Systemic Design Toolkit [31], systemic design is informed by both systems thinking and design thinking practices.

The systems-thinking [32, 44] aspect of systemic design encourages designers to see problems as part of interconnected systems rather than isolated issues. Donella Meadows, a pioneer of systems-thinking, defines a system as “an interconnected set of elements that is coherently organised in a way that achieves something... a system must consist of three things: elements, interconnections, and a function or purpose” [44, p.11]. For example, elements within an Architecture, Engineering, and Construction (AEC) sociotechnical system might include architects, engineers, builders, regulators, and consumers, which are interconnected through flows of information, materials, and finances to fulfil its purpose of delivering safe and functional built environments.

The design thinking components of systemic design situate knowledge about a system within an iterative and participatory design process. Design thinking provides tools for exploring how interventions at particular leverage points might influence a system. **Leverage points**, as defined by Meadows, describe aspects of a system that can be used to influence its behaviour, where a small change in one area can produce a major enduring change in another part of the system [32, 44]. For example, a leverage point in AEC sociotechnical systems could increase the number of available skilled workers to meet the demand for building new homes (see Table 1 for other examples of leverage points in AEC sociotechnical systems). Using design thinking methods, the systemic designer might ideate interventions to bring these leverage points into play, such as incentivising high school recruits to join the AEC industry with education discounts or by investing in robotics that help ageing workers continue to contribute their skills in less physically demanding ways. In systemic design, designers iteratively explore and prototype such interventions, aiming to understand how these decisions impact the health and behaviour of the wider system [31, 32, 53].

Systemic design has gained traction in global design communities; most notably, the Design Council recently adapted their Double Diamond framework to accommodate Systemic Design methods¹. However, to our knowledge, there are only a handful of papers that apply Systemic Design in HCI, with these usually relating to sustainable design [9, 27] or methodological research with HCI specialists [2, 10, 35].

Similarly, Transition Design [29, 33] has been proposed as a design paradigm that advocates for long-term, systemic societal transitions toward more sustainable futures. It emphasises the role of future-oriented visioning, theories of change, and multi-level interventions across sociotechnical systems. However, while *Transition Design* outlines the need to connect short and long-term

¹<https://www.designcouncil.org.uk/our-resources/systemic-design-framework/>

Table 1: Categories of leverage points and illustrative examples, inspired by [10], that seek to address a shortage of skilled workers in the Architecture, Engineering and Construction (AEC) industry.

Category	Examples of leverage points in AEC
Acting on the constants and parameters of the system.	Incentivising senior school recruits to join the AEC industry.
Acting on feedback loops and delays .	Creating a support program for women entering the AEC industry, who then encourage other women to join the industry. Alternatively a time delay for workers leaving the industry by creating opportunities for ageing workers to apply their skills in less physically demanding roles.
Changing information flows or system rules .	Outreach programs that inform senior school graduates and female recruits about the opportunities of working in the AEC industry, or using government incentives to ensure businesses train people to meet the demand for skilled workers.
Changing the systems' goals or its underlying worldview .	In a more drastic example, instead of protecting jobs the government might prioritise automating as many jobs as possible, thereby reducing demand for skilled workers and in conjunction the price of building homes.

interventions, there is limited guidance in HCI literature that shows how HCI-specific design methods should be sequenced or orchestrated in practice. Our work builds on the Transition Design agenda by introducing a structured approach to interleaving systemic and speculative design, and by contributing a novel epistemic output, systemic futures tensions, that help make such transitions possible in HCI.

As articulated by Bornes et al. [10], the characterisation of systemic design, as organisational and social, ignores how the design of specific artefacts, products, and services can impact a broader system. Indeed, Lin and Villari [36] suggest that systemic design, service design, and speculative approaches can “help service designers to deal with more systemic and future-related problems” [36, p.1]. For example, how the introduction of construction robotics might change the type of trade skills required for building structures in the AEC industry. However, there are no HCI-specific papers that focus on the overlap of systemic and speculative design at the level of human interactions with digital technologies.

2.2 Elements of Speculative Design

Informed by critical practices from art, the humanities, and social sciences [50, 61], speculative design aims to “challenge narrow assumptions, preconceptions, and givens about the role products play in everyday life” [21, p. 33]. To do so, the method creatively extrapolates present-day trends and technological innovations to question societal values [1]. For example, Auger’s [1] fictional *Audio Tooth Implant* imagines a reality where society’s progressively shrinking

computer chips can be implanted in a tooth. Their designed acrylic tooth that encases an electronic chip and the accompanying journalistic articles invite people to consider the relationship between technology and the human body. While some of the viewing public welcomed the imagined product’s convenience, others refuted a world where humans are synonymous with machines. This speculative approach is not concerned with measuring the usability or efficiency [3] of a real ‘audio tooth implant’. Instead, it aims to generate knowledge by provoking conversations about what people value or desire for the future, as well as how technologies reinforce or obscure these aspirations [21, 26].

Although speculative design has become a prominent approach in HCI, a common criticism of the method is its lack of clarity about what constitutes “good” or “bad” speculative design [50]. In HCI, there are a number of related approaches (e.g. design fiction [8, 18, 56], critical design [3], speculative enactments [22], fabulation [55], or material speculation [58]) and frameworks (e.g. the futures cone [11, 21, 25] or alternative presents[1, 17]) that designers might apply to structure their speculative design process. These might include written forms like future-based scenarios (e.g. [47]) or other narrative-based works (e.g. [41]), fictional products or services (e.g. [12]), performative outputs or materials that are empirically evaluated (e.g. [22]), and even fictional research papers (e.g. [39]). Understandably, these diverse possibilities have attracted criticism that there is little standardisation and clarity about what speculative design *is and is not* [4, 20, 28, 38, 42, 50, 62], making it difficult to review the quality of the research contribution [5, 40].

Acknowledging these challenges, Ringfort-Felner et al.’s [50] recent review of speculative design research in HCI and resulting descriptive taxonomy highlights the common qualities associated with “good” speculative design. Importantly, the authors caution readers against using the taxonomy as a checklist. Instead, it offers a shared vocabulary for designers to decide what kind of knowledge they aim to generate, based on the specific design context and cultural norms they seek to interrogate. Their taxonomy outlines nine qualities categorised into three types (speculative, discursive and process) that make “good” speculative design:

- (1) **speculative** - includes fictional, critical, and socio-political qualities of the speculative design that distinguish it from forms of affirmative design, which focus on problem-solving or increasing consumption,
- (2) **discursive** - includes experienceable and thought-provoking qualities, and
- (3) **process** - includes grounded, participative, reflected or well thought-out design processes, and playful or creative qualities that strike a balance between creativity and methodological rigour.

In this paper we use the qualities within this descriptive taxonomy to structure how speculative design can complement systemic design and vice versa.

First, to address historic challenges for grounding speculative design, we explain how systemic design can be used to link this speculation to empirical data about how the sociotechnical system operates (Section 2.3). We then describe how the fictional and critical aspects of speculative design can be used to critically reflect

on the leverage points, in an otherwise pragmatic approach to futuring in systemic design (Section 2.4). Finally, we argue that the *participative* quality of speculative design can be achieved with a combination of designer-led *and* collaborative activities (Section 2.5). When carefully orchestrated alongside systemic design practices, it is possible to strengthen a collaborative approach to speculation, an area that has historically been difficult to achieve in a corporate setting [51, 61].

2.3 Grounding Speculative Design with Systemic Design

Several scholars argue that speculative design must do more than imagine distant futures. It needs to be *grounded in the present*, extrapolating existing social and technological trends to expose their possible trajectories. As Auger [1] argues, envisioning the *distant* future holds conjectural baggage, “playing to spectacle and technocentric dreams rather than being based on logical trajectories or contained by the rules of real life” [1, p.12]. Instead, he advocates for alternative presents where design proposals “utilise contemporary technology but apply different ideologies or configurations to those currently directing product development” [1, p.12], acting as “a form of cultural litmus paper” [1, p.13].

The identification of behaviours in a system can help to ground socio-political qualities of speculation. As several scholars argue [1, 37, 62], *grounding* speculative artefacts in existing empirical findings and theoretical ideas is important. Ringfort-Felner et al. [50] stress the importance of grounding in speculative design to create artefacts that have relevance, reliability and credibility in academic and societal debates. However, it is not entirely clear *how* to do this in a robust and systemic way.

The application of **feedback loops** in systemic design can provide a useful mechanism for grounding speculative design in real-world sociotechnical system dynamics. Feedback loops are used in systemic design to understand trends and behaviours of macro phenomena. In systems thinking, feedback loops describe recurring chains of cause and effect in which actions produce outcomes that, in turn, reinforce or counteract the original behaviour [44]. *Reinforcing feedback loops* amplify existing dynamics [44], such as a continued influx of construction projects putting further pressure on the demand for skilled workers. In contrast, *balancing feedback loops* stabilise systems by constraining change, for example, training and/or attracting skilled workers from other countries, balancing their demand. Feedback loops offer a mechanism for grounding speculative design in present-day dynamics by making explicit how current trends operate and helping the designer to imagine the political or social consequences that might occur as these feedback loops intensify or break down.

Importantly, design researchers [1, 50] stress that successful speculative design demands a careful balance of analysis of the present and imaginings of the future. If the speculative designs stray too far into the future, they will be alienating, and if they are too obviously plausible, they will lack the ability to challenge existing beliefs and inspire discourse. While systemic design could help to ground speculation, its pragmatism could risk designs taking on a more normative short-term appeal; a balance that is difficult to strike. This paper attempts to provide a structured approach that

helps researchers navigate critical imaginings of the future and the pragmatics of systemic change.

2.4 Fictional and Critical Qualities of Speculative Design Enhance Systemic Design

Imaginings of the future are a vital aspect of speculative design. However, contrary to common assumptions, speculative design does not aim to predict the future. Instead, it uses the future as a mechanism to suspend disbelief [21]. By designing for a reality yet to occur, researchers can move beyond expectations since the future is ultimately unknown and holds multiple possibilities [11]. Dunne and Raby, who helped to popularise speculative design, were interested in what makes a preferable future “preferred” for different groups of people and how “working with experts, including ethicists, political scientists, economists, and so on, generate futures that act as catalysts for public debate and discussion about the kinds of futures people really want” [21, p.6]. Importantly, the tradition of speculative design aims to move beyond future-proofing or solution-finding for the fickle future, and instead uses these futuring frameworks to understand what society values and **critique** why this might be.

While Systemic Design engages with futuring practices, by itself, it lacks critical orientation. Systemic design excels at mapping complexity, identifying feedback loops, and revealing leverage points within existing structures [31, 36]. However, it risks reinforcing prevailing assumptions by optimising existing practices or realising unchallenged desired futures [36]. Speculative design complements this by introducing critique as a mode of inquiry. As Lin and Villari [36] argue, speculative approaches can surface tensions, uncertainties, and conflicts that systemic analyses alone may render invisible, enabling collective reflection on long-term implications beyond immediate feasibility. Similarly, Borne [9] demonstrates how systemic models, such as causal loop diagrams, can act as conversational artefacts that support debate and scenario comparison, a role that speculative artefacts further extend by making potential consequences legible as real objects. In doing so, speculative critique helps researchers move from system-level insights to a critical examination of how system interventions with technologies may reinforce or disrupt existing patterns in a sociotechnical system.

2.5 Interleaving Speculative Design Leadership with Participatory Systemic Design

A common criticism of speculative design is its designer-led orientation, which risks foregrounding a singular, and often privileged, vision of how society should function [43]. Prior work shows that speculative practices are frequently conducted by a small group of experts whose perspectives, values, and assumptions shape both the framing of futures and the technologies imagined [14, 19, 43]. In particular, Arturo Escobar’s [23] critique of development as a discourse that “made the Third World” (and can be “un-made”) stresses the need to interrogate how design practices construct particular futures and marginalise others. This tendency to design for rather than with(in) sociotechnical systems can obscure how systems operate in practice and risk reproducing existing inequalities [36]. Such top-down approaches sit uneasily with systemic design,

Table 2: Comparison of systemic design and speculative design across key dimensions, informed by [1, 10, 21, 32, 50].

Dimension of Primary Focus	Systemic Design	Speculative Design
Time-horizon	Present	Future
Analytical scale	Macro	Micro
Mode-of-inquiry	Collaborative & Empirical	Design-led & Conceptual
Purpose	Pragmatic outcomes	Critical reflections

which depends on participation from system representatives to understand macro-level dynamics.

HCI research has increasingly explored participatory speculative design to broaden the perspectives that inform future imaginaries [14, 19, 51]. However, prior studies show that greater collaboration alone does not resolve key challenges. Participants may remain constrained by their own experiences [19], struggle with the ambiguity of speculation, or revert to normative thinking [13], particularly in corporate or novice settings [51]. These findings suggest a tension between democratising speculation and the expertise required to meaningfully challenge dominant assumptions when speculative design is carried out by itself, albeit in collaborative ways. Our work explores what might happen when speculative design is retained as a designer-led activity, and instead informed by collaborative activities *inherent* to systemic design carefully sequenced and interleaved with speculative designer-led practices.

2.6 Summary of Comparison between Systemic Design and Speculative Design

In summary, Speculative design and systemic design offer distinct, yet complementary, ways of engaging with complex sociotechnical challenges. Table 2 summarises their primary foci on dimensions of **Time-horizon** and **Scale-of-analysis**, **Mode-of-inquiry** and **Purpose**.

Both approaches incorporate the present and the future time horizons to varying degrees. Speculative design typically pushes beyond the immediate present to explore futures which are distant [21], alternative [1], or even preposterous [30], using fiction and imagination to suspend disbelief and provoke critical reflection. In contrast, systemic design is more firmly anchored in the present [36], focusing on existing structures, behaviours, and feedback loops in order to understand how systems currently operate and where intervention may be possible [10]. While systemic design may incorporate future scenarios [32], these are usually constrained by plausibility and grounded in observed dynamics rather than deliberately exaggerated or provocative futures [36].

The two approaches also differ in their analytical scale. Systemic design explicitly adopts a macro-level perspective, examining relationships between multiple entities and resources within a complex system [44]. Speculative design in HCI, by contrast, often operates at a micro-level, examining human interactions with particular technologies and the experiential, ethical, or normative implications of those interactions [61]. Although some speculative projects

extrapolate these interactions to broader societal concerns [26], this systemic perspective is not always made explicit or analytically structured.

Differences are also evident in their mode-of-inquiry and how participants are engaged. Participation is foundational to systemic design, which relies on the involvement of system stakeholders to surface diverse perspectives and to build shared understanding of complex dynamics [32]. Speculative design, historically, has been more designer-led, with designers crafting artefacts or scenarios that invite interpretation and debate [21, 43]. While recent work has increasingly explored participatory speculative approaches [14, 19, 24], tensions remain between the expertise required to challenge dominant assumptions and the desire to democratise future-making.

Finally, the two approaches diverge in their primary purpose and outputs. Speculative design is oriented toward critical discourse, so its artefacts are intended to question values, expose assumptions, and provoke debate rather than propose immediately actionable solutions. Systemic design, by contrast, is more explicitly pragmatic, aiming to identify leverage points and inform interventions that can be implemented within existing systems

The complementary differences between systemic design and speculative design suggest an opportunity to combine these methodologies. The result is the Systemic Futures Dialogue, which carefully orchestrates systemic and speculative design activities and generates a novel output, **systemic future tensions**. Generated through the careful sequencing of the dialogue activities, designers structure their inquisition so that they follow the “golden thread” [7] of information; from micro insights in the present, to building macro-level system dynamics, extrapolating this out to imagine macro futures, then realising these as micro-level technologies. As a result, the tensions capture contradictions exposed by considering both the macro-level pragmatism and collaborative orientation of systemic design, with micro-level and critical designer-led speculation.

3 INTRODUCING THE SYSTEMIC FUTURES DIALOGUE

We introduce the Systemic Futures Dialogue (Figure 1), which integrates HCI traditions in speculative design with systemic design practices. It provides a framework for designers and industry stakeholders to navigate the differences between systemic and speculative design in complementary rather than conflicting ways. In doing so, it offers a structured way for community representatives and HCI researchers to collaboratively examine how specific technologies may either disrupt or reinforce entrenched patterns of behaviour within sociotechnical systems. Finally, it responds to long-standing challenges in applying speculative design in industrial contexts [61] by providing a practical means for organisations to engage in critical reflection.

The framework was inductively generated from a reflection on the design work we performed with the AEC industry, drawing inspiration from research through design traditions [28, 62], and from existing literature that indicates an opportunity to combine macro-level methods from systemic design with HCI traditions in speculative design [10, 36]. Reflecting on our design process, artefacts, and existing literature helped us articulate what it means,

in practice, to carry out systemic and speculative design in conjunction *with* industry participants. The Systemic Futures Dialogue captures these reflections.

We used the dimensions in Table 2 to motivate the Systemic Futures Dialogue. The framework is structured as a 2x2 matrix, which positions the different design foci along two axes: **present-future** on the *x* axis and **micro-macro** on the *y* axis. In each quadrant, particular design activities are carried out, sometimes in parallel or independently. Some quadrants adopt a more collaborative approach, inspired by systemic design, while others are more designer-led according to speculative design traditions. Researchers move in a 360-degree motion from the [present, micro] quadrant to [present, macro], across to [future, macro], which is then disrupted by critical debate in the [micro, future], feeding back into the [micro, present]. These steps can also be described as *Observe*, *Model*, *Extrapolate* and *Critique*.

The dialogue culminates in the final stage, *Reflect*, where designers compare outputs from the *Critique* phase to the pragmatic solutions developed in the *Model* phase. The result is a set of **systemic futures tensions**, which interrogate the consequences of the proposed systemic changes by identifying how their projected outcomes may be at odds with collectively desired futures. Once *reflect* is reached, researchers might start once again at observe to probe for a deeper understanding of the sociotechnical system if significant tensions are found between desirable futures and proposed systemic change.

3.1 Observe [Micro, Present]

The Systemic Futures Dialogue begins in the bottom-left quadrant of the framework, which represents a micro-level focus on the present. As is common in many design research traditions [37], the methods employed in this starting quadrant are oriented toward discovery and sense-making, with the aim of understanding the existing design space. These methods may include user interviews, ethnographic observation, contextual inquiry, diary studies, and desktop research, all of which seek to understand individuals' lived experiences with current technologies. Gathering these insights from a range of different actors in the system (e.g. in our AEC case study, industry representatives from the regulatory bodies, commercial companies, unions, as well as educators) helps researchers develop an empirically grounded understanding of dynamics across the broader system. It is possible that different starting points in the dial exist, and we leave this open to the research team to decide according to the unique challenges they face.

3.2 Model [Macro, Present]

Moving to the second quadrant, **model [macro, present]**, the focus shifts from individual experiences to a system-level view of current conditions. Insights generated in the *observe* quadrant are synthesised to model how resources (e.g. knowledge, money, materials, or other forms of capital) flow through the system, and to identify *feedback loops* that reinforce or counterbalance existing behaviours. At this stage, a representation of the system is collaboratively created and validated with industry participants, and potential *leverage points* for positively influencing the system are identified.

A range of system-modelling techniques may be employed, including causal loop diagrams [57], systems mapping [31], stock-and-flow diagrams [44], leverage analysis [46], and gigamaps [53]. In practice, systemic designers often rely on the systems mapping process articulated in the systemic design toolkit [32]. This involves a collaborative approach to mapping out the variables and causal loops in a system, then identifying. By doing so, researchers can zoom out to see how challenges that appear discrete at the micro level are interconnected. Working in the [macro, present] quadrant makes visible how interventions in one part of the system may generate unintended consequences (both positive and negative) elsewhere, supporting more informed and responsible design decisions.

3.3 Extrapolate [Macro, Future]

In the third quadrant, **extrapolate [macro, future]**, insights from the preceding quadrants are used to collaboratively imagine alternative futures at the level of the whole system. Here, the present-day system is placed into hypothetical conditions to explore how its structures, relationships, and feedback loops might evolve, intensify, or break down over time. Rather than predicting outcomes, this quadrant focuses on extrapolating existing dynamics to examine their potential consequences under different future conditions.

Futuring frameworks such as the Futures Cone [25], which distinguishes between probable, plausible, possible, and preposterous futures, or Candy's Future Arcs [11], which consider trajectories of growth, collapse, discipline, or transformation, might be used to structure this exploration. These frameworks help designers systematically extend present-day trends into alternative system-level futures. The resulting scenarios may take the form of narratives, storyboards, or other high-level representations that describe how work, practices, or processes unfold in the extrapolated future.

Crucially, these future-based scenarios are grounded in the system dynamics articulated in the **Model [macro, present]** quadrant. They are generated by asking "what if" questions about how the identified feedback loops might respond to changes introduced at different leverage points. For example, how a reinforcing feedback loop might shift if a leverage point identifying new government policies is pulled to accelerate technology adoption. As a result, the scenarios remain deliberately macro in scope, focusing on systemic patterns rather than individual interactions.

This quadrant draws on both systemic and speculative design traditions. From systemic design, it inherits a concern for coherence and continuity with present-day dynamics; from speculative design, it adopts an orientation toward imagining futures that may extend beyond strict plausibility in order to surface values, desires, and points of critique. In doing so, the *extrapolate* quadrant enables designers to reflect critically on present-day actions by examining their long-term systemic implications.

3.4 Critique [Micro, Future]

In the final quadrant, **Critique [micro, future]**, the system-level futures developed in the previous **Extrapolate [macro, future]** quadrant are translated into micro-level interactions with specific, imagined technologies. Here, speculative artefacts are created to depict how individuals might interact with these technologies within

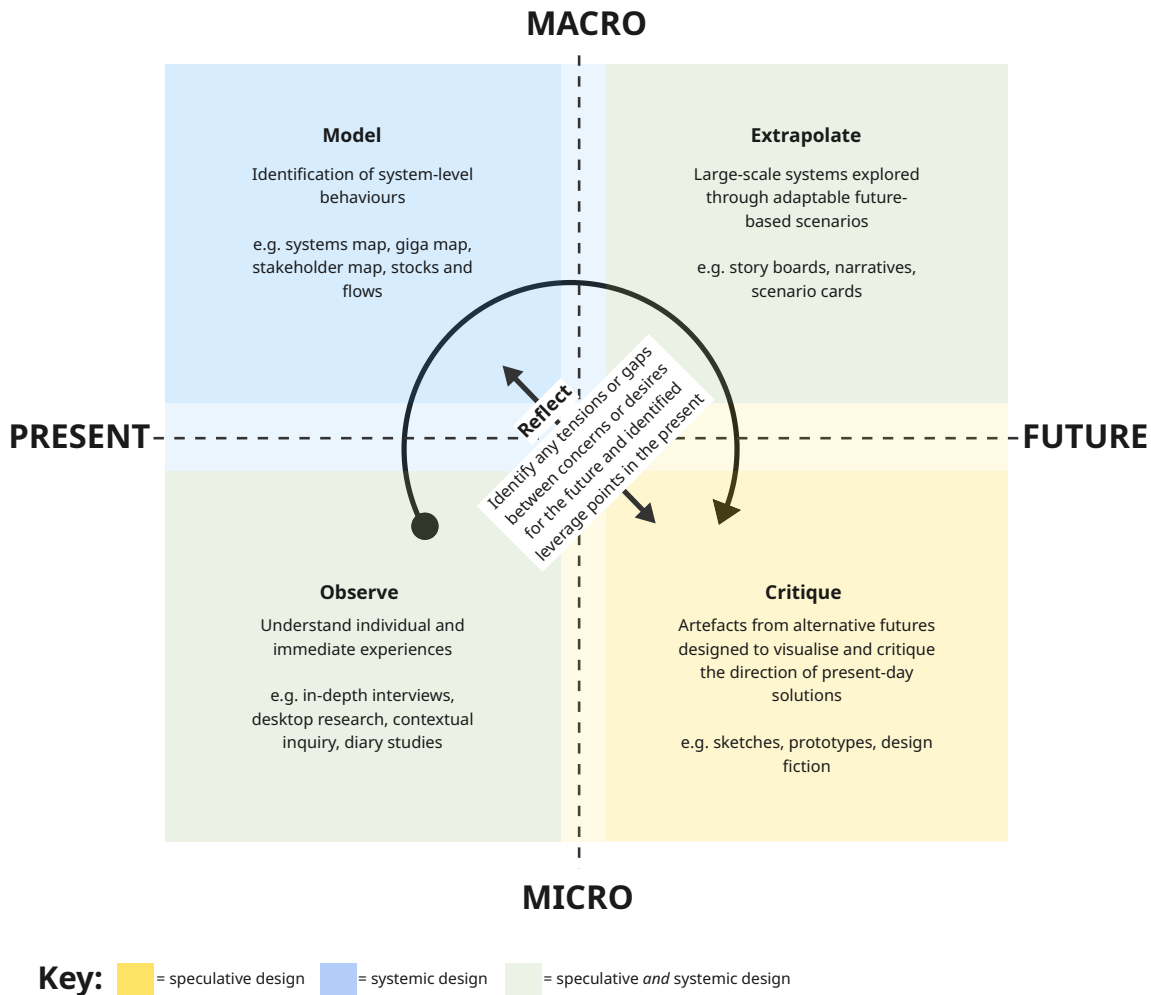


Figure 1: Using the Systemic Futures Dialogue, design practitioners move between observe > model > extrapolate > critique > reflect. The output of each quadrant informs the next, building a multi-layered approach that considers both macro systemic trends and micro opportunities to actively shape the future through the present.

the future worlds articulated by the scenarios. This quadrant draws most strongly on speculative design traditions, and the artefacts may take a variety of forms, including sketches, low- or high-fidelity prototypes, and design fictions such as artefacts from the future (e.g. newspaper clippings, policy documents, or product advertisements).

We propose that the creation of these speculative artefacts is primarily led by the design researcher, drawing on their design experience to craft artefacts that are conceptually provocative. However, crucially, these artefacts are not developed in isolation and are informed by the participatory insights generated in earlier quadrants. One of the aims of the Systemic Futures Dialogue is to ground designer-led speculative design in participatory insights of the system, developed through systemic design activities.

Once created, the speculative artefacts can function as probes that are reintroduced to participants to elicit reflection and discourse. Participants are invited to discuss whether these imagined

technologies align with or challenge their desired futures and why this is so. To be effective, the artefacts must “strike a balance between creativity and methodology rigour” and encourage discourse that surfaces underlying values rather than prompt affirmative design qualities that focus on problem solving or increasing consumption [50]. These discussions enable critical reflection about how future technologies inform everyday practices and societal norms.

3.5 Reflect [tensions between Micro-Future and Macro-Present]

Finally, by looking diagonally across the Critique [micro, future] and Model [macro, present] quadrants, researchers can instigate reflection between future-oriented critiques and present-day system dynamics. This reflection focuses on interpreting what the critical

discourses elicited by speculative artefacts imply for the leverage point solutions identified in the current system.

This reflection phase generates **systemic futures tensions** that articulate the trade-offs between participants' desires for the future and the actions or interventions that appear most feasible or influential in the present. Importantly the tensions do not emerge simply undertaking systemic design and speculative design as separate activities. The systemic futures tensions are informed by both the forces at play within the system and speculative critique, through careful sequencing that helps the designer *move between micro and macro perspectives*, as well as *pragmatic and critical perspectives*. This makes it possible to identify the contradictions between macro-level systemic change and the micro-level materialisation of this change, as technologies sent from the future. The practical reality of examining the proposed solutions, helps to surface aspirations that may be at odds with the more abstracted [macro, present] propositions for systemic change, exposing where solutions require deeper investigation.

For example, industry leaders may identify leverage points that *prioritise productivity* in the present system, while simultaneously expressing a desire for futures that *avoid burn out*, from constantly churning out products at an increased pace. Rather than treating such tensions as problems to be solved, we invite researchers to examine whether present goals and future desires are genuinely incompatible, to explore why they might conflict, and to consider how present-day actions need to change to create a future that balances the values and needs of diverse actors within the system.

4 CASE STUDY AND DESIGN APPROACH

In this section, we illustrate our approach through a project that used the Systemic Futures Dialogue to investigate future work practices in the Architecture, Engineering and Construction (AEC) industry.

4.1 Challenges in the Architecture Engineering and Construction Industry

Globally, the AEC industry is essential for creating and maintaining infrastructure that supports basic human needs. However, the industry has come under increased scrutiny due to a lack of sustainability, safety and productivity improvement. The perceived stagnation of the AEC industry across different work facets has attracted interest in how "Industry 4.0" innovations can improve the way work is done. Although Industry 4.0 has varying interpretations [34, 45, 48], we broadly define it as a technological and organisational transformation resulting from advancements in digitally powered inventions [34].

Digital innovation has also supported the development of new work methods and processes. One prominent area, generally referred to as Modern Methods of Construction (MMC), encompasses a broad range of innovations, most of which aim to move construction work from onsite to offsite factories [49]. MMC is a system that involves product innovation (e.g. panellised walls), innovation to processes (e.g. lean logistics), digital tools (e.g. BIM), changes involving integrating design with manufacture, and an integrated supply chain. It includes approaches like modular building and prefabrication [49], where standardised sections, such as entire

bathrooms or individually fabricated parts, are built in a factory before being transported and installed on the construction site. These approaches are attractive as they "offer potential for reductions in cost, time, defects, health and safety risks and environmental impact and a consequent increase in predictability, whole life performance and profits" [59, p. 1]. While concepts like prefabrication date back to London's Crystal Palace in the 1850s, Industry 4.0 technologies, particularly robotics, have made it more feasible to scale these approaches and heralds the beginnings of industrialised construction that adopts a factory driven process of production with a revised set of skills and capabilities for its workforce.

Although Industry 4.0 has been regarded as an opportunity for innovation in the AEC industry, there are several challenges to its adoption. The most critical issues include access to training programs that includes relevant technologies and new production methods, mental health and wellbeing, shortages of skilled labour, cost of technology investment, devaluation of traditional skills, fragmented services and project processes, as well as legal and regulatory barriers [15, 54]. These challenges are **systemic**, meaning they have multiple factors across different entities and groups of people across the industry that influence them. For example, access to training is impacted by various social factors, including government funding, paid time-off for workers, cost of educational resources, awareness of programs and availability of qualified instructors. Since systemic issues are often ambiguous and slow to evolve, progress toward meaningful change has not been as rapid as some expected [48, 54]. With looming societal pressures, like a global housing crisis, the AEC industry is under pressure to address these challenges and see improvements as a collective.

4.2 Case Study Research Objectives

This 18-month case study examined how emerging technologies may shape future work practices in the building and construction industry, with a particular focus on what makes technological interventions desirable for both workers and organisations. Working with industry partners across commercial construction, building services, prefabrication, regulation, education, and labour unions, the study aimed to surface the systemic forces that enable or constrain innovation and to identify future opportunities for improving working conditions and productivity.

Specifically, the case study sought to: (1) explore how emerging technologies may impact future work practices and working conditions across diverse roles and skill levels; (2) inform strategies for managing transitions in work practices associated with technological change; (3) examine implications for skills, training, and workforce development, including risks of deskilling and challenges of attracting, retaining, and transitioning skilled workers; and (4) identify how technological adoption might be leveraged to enhance productivity while supporting fair and sustainable industrial relations.

4.3 Participants

The project involved 17 representatives from different areas of the architecture, engineering, and construction (AEC) industry. In Appendix A.1, we provide an overview of the participants' backgrounds and their involvement across the various phases and steps

of the project. These participants represent a diverse cross-section of specialisations, which helped us gather information about the AEC industry and test our ideas from a variety of different angles. Before the research phase, participants were asked to review a plain language statement and sign a consent form. Participants were not reimbursed for their participation, since the research was sponsored by their organisation and carried out during their regular working hours.

4.4 Method

We developed the Systemic Futures Dialogue as an approach to identify the system-level influences across the AEC industry and to critically engage with future possibilities of work practices. A summary of the method's phases and steps is shown in Figure 2.

4.4.1 *Observe [Micro, Present] - Interviews and Desktop Research.*

We began with semi-structured interviews with industry representatives (n=9) from regulatory, commercial, and education sectors within the AEC industry. The interviews were informed by desktop research of the issues facing the AEC industry and addressed three broad areas: (1) The primary concerns regarding the impacts of Industry 4.0; (2) How they are responding to the concerns; and (3) What new technologies are likely to be introduced and any expected challenges from their use. Each interview lasted approximately 90 minutes.

Interviews were transcribed and analysed using Dovetail² followed by Reflexive Thematic Analysis (RTA) [16]. Analysis was conducted inductively by the first author, who drew on both the desktop literature and prior experience working in organisational contexts. The process involved familiarisation with the data, line-by-line coding, and iterative clustering of codes into themes. To support reflexivity and grounding, these themes were reviewed and discussed with industry stakeholders (n=6), who contributed their own interpretations of the findings. This phase generated foundational insights into subjective present-day concerns and priorities, which informed subsequent design activities.

4.4.2 *Model [Macro, Present] - Systems Map.*

To develop a macro-level understanding of the AEC industry, we constructed a systems map representing the industry as a sociotechnical system. We adopted a systemic design approach that emphasises practical sense-making and visual synthesis. In particular, we followed the Systems Mapping Academy's toolkit³ to create a representation of the system as it exists today.

The systems map was initially developed by the first author and validated by industry stakeholders (n=6). The process began by defining the system boundaries, focal challenges, and guiding research questions, drawing on findings from the *Observe [micro, present]* phase. We then identified key variables, which are nodes within the system representing tangible or intangible resources (e.g. levels of skill, capital, wellbeing, or regulation), and mapped causal relationships between them. These relationships indicate influence rather than sequence, distinguishing the map from a process or flow diagram.

Variables and relationships were refined through multiple iterations until the research team agreed the map captured the system's key dynamics. Reinforcing and balancing feedback loops were then identified and analysed. Finally, the research team collaboratively identified thematic regions within the map and developed narrative descriptions to communicate how different parts of the system interact. The map was validated and refined based on feedback from industry participants.

4.4.3 *Extrapolate [Macro, Future] - Scenario-Based Design.*

Building on insights from *Observe [micro, present]* and *Model [macro, present]*, we developed a set of future-based scenarios to explore how the system might evolve under different conditions. Scenario development was structured using Candy's Future Arcs [11], which articulate four possible trajectories: continuation of current trends, discipline through regulation or incentives, transformation through new technologies, and systemic collapse requiring radical change.

Each scenario examined how different regions of the systems map might shift under these conditions, with particular attention to the implications for workers' pains and gains. These scenarios were co-developed with industry stakeholders in a participatory workshop (n=8) and iterated based on their feedback. These scenarios focussed on systemic patterns rather than specific technological interactions.

4.4.4 *Critique [Micro, Future] - Speculative Probes.*

Drawing on the scenarios generated in *Extrapolate [macro, future]*, the research team developed a set of speculative probes depicting micro-level interactions with imagined future technologies. These artefacts were intentionally designer-led, and developed within the HCI research team to leverage design expertise to create artefacts that balance provocation and plausibility. In later sections, we reflect on this choice and its implications for integrating systemic and speculative approaches.

The speculative probes were generated through a 1.5-hour ideation workshop, in which the research team used the scenarios as prompts to imagine technologies and practices associated with each future trajectory. Using a diverge-converge process, researchers first generated ideas individually before collectively discussing and refining them. Selected concepts were then further developed by the lead researcher into speculative sketches. The speculative probes were introduced to AEC industry stakeholders (n=11) in a participatory workshop. Participants discussed what they found desirable or undesirable about the probes and reflected on the values and assumptions embedded within them.

4.4.5 *Reflect - Affinity Mapping.*

In the final collaborative workshop, industry participants (n=11) reviewed the systems map, future-based scenarios, and speculative probes. Participants first identified leverage points within the present-day system and proposed potential interventions. The workshop participants then worked in groups to discuss the scenarios and speculative probes, documenting what they perceived as desirable or undesirable in each future. The four-hour workshop was conducted in a hybrid format, with contributions captured through a combination of physical and digital sticky notes. Using

²<https://dovetail.com/>

³<https://www.system-mapping.com/>

Key: ■ = speculative design ■ = systemic design ■ = speculative and systemic design

RESEARCH PHASE	1) OBSERVE [MICRO, PRESENT]		2) MODEL [MACRO, PRESENT]	3) EXTRAPOLATE [MACRO, FUTURE]	4) CRITIQUE [MICRO, FUTURE]	5) REFLECT [MICRO FUTURE] + [MACRO PRESENT]		
APPROACH	Systemic Design and Speculative Design		Systemic Design	Systemic Design and Speculative Design	Speculative Design	Systemic Design and Speculative Design		
STEPS	1.1	1.2	2	3	4	5.1	5.2	5.3
RESEARCH METHOD	One-on-one semi-structured interviews and desktop research	Research insights validation	Systems mapping	Future based scenarios generated in a participatory workshop	Speculative design	Leverage points identification + desirable/undesirable futures identification [actual timing]	Affinity mapping (comparing leverage points and desirable + undesirable futures)	Design tensions validation
OUTPUT	Draft research insights	Validated research insights	Systems map	4 x Future-based scenarios	8 x Speculative probes (2 per future-based scenario)	<ul style="list-style-type: none"> Leverage points Desirable + undesirable futures 	Draft Design Tensions	Validated Design Tensions
PARTICIPANTS	P2, P5, P6, P11, P13, P14, P15, P16, P17 (n=9)	P1, P2, P5, P6, P11, P12 (n=6)	P1, P2, P5, P6, P11, P12 (n=6)	P1, P2, P3, P5, P6, P11, P12, P13 (n=8)	N/A	P1, P2, P3, P5, P6, P7, P8, P9, P10, P11, P13 (n=11)	N/A	P1, P2, P3, P4, P5, P6, P11, P13 (n=8)
PARTICIPATION APPROACH	Designer-led	Participatory workshop	Designer-led / participant validated	Participatory workshop	Designer-led	Participatory workshop	Designer-led	Participatory workshop
REFLECTIONS FOR FUTURE APPLICATIONS	The semi-structured interviews and desktop research insights informed the dynamics captured by the systems map in the model phase.		The systems map was created by the research team and validated by participants. Future research might examine creating the systems map with more participatory methods as suggested in [29].	The feedback loops identified in the systems map from step 3 helped to inform the future-based scenarios. It was possible to ask participants to imagine what might happen to these feedback loops if the system was placed under different pressures or constraints.	The design experience of the research team made navigating the balance between plausible futures and challenging critique approachable. However, these designs were still informed by input from earlier participation with industry representatives. On reflection, we believe this can help to strike a balance between design expertise and providing opportunities for input.	Due to time constraints, the leverage points and desirable/undesirable futures were identified in step 5.1. Ideally the leverage points would be identified after step 3 and desirable/undesirable futures after step 4, which we discuss in the limitations.	Looking across the Systemic Futures Dialogue it is possible to see tensions between the ideal future, proposed leverage points, and how technologies at the micro level instantiate these ideas. These tensions help to identify opportunities for future empirical research, helping sociotechnical systems actively build a desired future in the present.	Although the affinity mapping was carried out by the design team, it might be that future work does this in participation with industry representatives. Ultimately it is important for industry representatives to review and validate the final tensions that set the stage for future research.

Figure 2: Summary of methods and participants involved in each design stage of the case study.

affinity mapping, the leverage points and desirable or undesirable futures were summarised by the lead researcher post workshop.

Written data from the workshop was analysed using affinity mapping. Notes related to present-day system interventions and future-oriented reactions were clustered separately and thematically analysed. The research team then compared themes across the macro-present and micro-future perspectives, resulting in the identification of three core **systemic futures tensions**. These tensions articulate points where present-day opportunities for change conflict with participants’ desired futures. These tensions are a important generative output of the Systemic Futures Dialogue, capable of structuring future research agendas focused on navigating and reconciling systemic trade-offs. These design tensions were then validated in meeting with industry representatives (n=6).

4.5 Positionality Statement

This research was conducted as part of a collaboration between The University of Melbourne and the Building 4.0 Cooperative Research Centre (CRC), an industry-led initiative focused on advancing technological capability and working conditions in the Architecture, Engineering, and Construction (AEC) industry. The interdisciplinary research team comprised of scholars from human-computer interaction (HCI), labour relations, and AEC domains, informing both the framing of the research problem and its interpretation.

The first author identifies as a woman with a background in co-design, HCI, and management consulting in both IT and AEC-adjacent contexts. While she had prior experience working with AEC clients, she had not worked directly within the industry, positioning her as a partial outsider. This influenced the study in

several ways: it required participants to articulate domain-specific practices and assumptions, while also enabling critical distance in questioning norms. Her professional experience informed the design of participatory activities and speculative artefacts, as well as the interpretation of participants’ responses. Additionally, her personal experiences being in a cultural and gender minority within male-dominated workplaces sensitised her to issues of inclusion and belonging, though it may have limited her ability to fully interpret gendered experiences outside her own.

The second and third authors identify as men with extensive experience in the AEC industry, contributing insider perspectives on industry practices, constraints, and values. Their involvement supported the contextual grounding and validation of interpretations. The fourth male author, also identifying as a man, and brought expertise in industrial relations, shaping our analysis of labour dynamics, regulation, and power structures. The remaining authors (two identifying as men and one as a woman) have backgrounds in HCI and human-robot interaction, contributing expertise in technological design and interactional analysis.

The combination of insider and outsider perspectives shaped the formulation of research questions, the design of artefacts, and the interpretation of findings. In line with Reflexive Thematic Analysis (RTA) [16], the findings are understood as co-constructed through the interaction between participants’ accounts and the first author’s professional and experiential perspective, since they carried out any initial coding of verbal or written data. The other co-authors also brought their own positions to bare on the data, helping to refine the final artefacts and design outputs, from different insider and outsider perspectives.

Power dynamics were present in multiple forms. Participants, as industry professionals, held domain expertise, while researchers shaped the structure of engagement and interpretation. Additionally, the project was funded through an industry–academic partnership. While academic researchers retained autonomy over research design and artefact development, industry researchers made valuable contributions to defining research directions and priorities. This collaboration informed and constrained the speculative outputs. Whilst the research aimed to investigate the intersection of critical provocation with practical relevance (in line with prior work on speculative design [1, 51]), it is possible that the industry-academic collaboration led to more plausible speculative scenarios.

5 RESULTS

In this section, we report on the findings in each stage of the case study. We present the artefacts and the knowledge they generated, reflecting on how this knowledge iteratively informed each subsequent stage of the research process.

5.1 Observe [micro, present]

The reflexive thematic analysis of the academic expert and stakeholder interviews surfaced several key themes that address to the major concerns and priorities in today’s AEC industry:

- (1) **SKILLS: There is demand for skilled workers and a push for greater workforce diversity.** A shortage of skilled labour is driving up project costs, while ongoing diversity and inclusion challenges limit recruitment from a broader talent pool of diverse abilities, experiences, and identities.
- (2) **TOOLS & PROCESSES: There is inconsistent adoption and interoperability between tools and processes.** Although various digital tools and processes are being used across the industry, a lack of integration leads to fragmented data, inefficient information sharing, and record inconsistencies.
- (3) **POLICY & CULTURE: The AEC industry has many different actors with competing interests, levels of digital maturity, and appetite for change.** While these differences make it challenging for people to collaborate, the right policy and culture development can emphasise and support their common goals.
- (4) **VALUES: Sustainability, safety, and quality are core shared values in the AEC industry.** In an environment with competing agendas, reducing carbon emissions, improving worker safety and maintaining output quality are shared goals across the AEC industry.

5.2 Model [macro, present]

The output of this stage was a systems map and a set of region stories, which provide a macro representation of the present-day AEC sociotechnical system. The complete systems map is very large, and shown in a compressed format in the supplementary material (Appendix A.2). A section of the systems map (which is more legible) is shown in Figure 3. The figure illustrates key components of the system map, including variables, feedback loops, regions, region stories and leverage points, which come together to create a rich understanding of AEC sociotechnical systems.

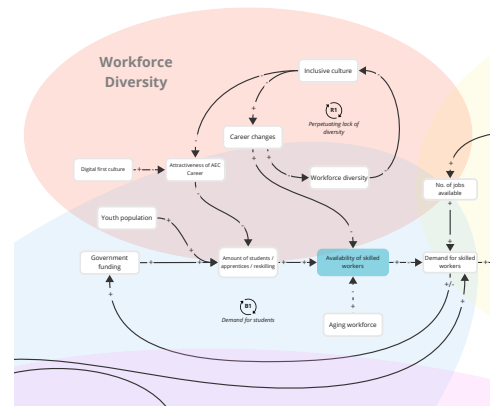


Figure 3: Section of AEC Systems Map showing selection of variables, reinforcing loops (R1) and balancing loops (B1)

The variables are individual nodes in the systems map and capture the movement of resources or value in the system. For example, “amount of money to build a home”, “available skilled workers” or “amount of building contracts” are all relevant variables. Insights from observations, interviews and relevant prior literature are used to connect the variables, with arrows showing how the different variables positively or negatively influence each other.

Once the variables are mapped, feedback loops are identified. Feedback loops exist where actions in one area, such as a new technological breakthrough or a policy change, can have cascading effects on others [44]. Two types of feedback loops were identified. **Reinforcing loops [R]** connect variables that amplifies a pattern same direction (e.g. in Figure 3 R1: a lack of diversity in the industry creating a culture where recruits from different backgrounds feel unsupported, leading to a reduced pool of potential employees and continued pressure on the current workforce) and **Balancing loops [B]** show flow of variables that create equilibrium (e.g. in Figure 3 B1: as the demand for workers increases, government funding encourages more students to join, this is balanced by an ageing population who retire from the industry or those who leave the industry).

Once all the feedback loops were named, the research team then identified regions on the systems map that tell a story about the dynamics in the AEC industry. These regions include: *workforce diversity*, *cost of building homes*, *education and reskilling*, *external forces for change*, *awareness and access to new knowledge and tools*, and *interoperability and information sharing* (shown as coloured regions in Appendix A.2)

In the participatory workshop, industry stakeholders identify opportunities for change for each region, also known as “leverage points” in systemic design practice [31]. A summary of these leverage points can be found in Figure 4. Using affinity mapping these leverage points were placed on the systems (Appendix A.2).

The systems map visualises the interconnected challenges at the macro level. It highlights how efforts to “solve” one challenge can unintentionally create negative impacts elsewhere. This awareness of consequences allowed us to think critically about how the system might respond under different conditions, laying the groundwork for future-based scenarios in [macro, future]. For example, without

Leverage Points		
System Map Regions	Workforce diversity	<ul style="list-style-type: none"> • Offer jobs and tools that support a diverse workforce • Offer additional support with mentorship networks • Keep going with government mandates and reward diverse recruiting
	Cost of building homes	<ul style="list-style-type: none"> • Standardise building approaches and promote modern methods of construction (MMC) to increase productivity • Influence metrics to drive innovation and productivity • Government and industry leadership for standardising building approaches
	Interoperability and information	<ul style="list-style-type: none"> • Encourage early contractor involvement • Measure success of digital tools and share knowledge • Everyone knows a bit of construction management • Encourage a competitive market that plays an infinite game
	Education and reskilling	<ul style="list-style-type: none"> • Upskilling made easier through opportunities like micro-credentials • Mentorship and purpose-designed education • Standardisation and assessment of new skills
	Awareness and access to new knowledge and tools	<ul style="list-style-type: none"> • Innovation cost cuts for small to medium businesses to increase access (ability to wear the costs and increase the margins) • Build awareness of new tools through the education system • Encourage adoption with show not tell and gamified approach
	External forces for change	<ul style="list-style-type: none"> • Share knowledge and demonstrate value of innovation • Mandates for innovation • Reward innovation • Government backed modern methods of construction

Figure 4: Leverage points, showing aspects of the AEC systems that could be modified to significantly influence another part of the system.

adequate support for education and awareness, introducing new technology to address a shortage of skilled workers could actually reinforce this scarcity, as current trends show that small and medium-sized businesses may struggle to keep up with the cost of upskilling and acquiring new technologies and processes. By visualising these interconnected macro issues, the systems map enabled us to tell a more complete story about how the system might respond to change and to imagine alternative futures in our scenarios.

5.3 Extrapolate [macro, future]

We created four future-based scenarios, informed by the insights generated from the first two quadrants of the Systemic Futures Dialogue (*Observe [micro, present]* and *Model [macro, present]*). The scenarios were informed by micro-level insights from industry participants on the use of technologies in work practices, as well as a macro-level understanding of how industry challenges interact. A copy of each scenario can be found in the supplementary materials.

5.3.1 Scenario 1 (probable) - Artificial intelligence (AI) pushes innovation, for some.

This scenario (Figure 5) simulates a probable future, where we continue on as-is [11], and AI is one of the few changes that impact the system. In this future, it is assumed that present reinforcing loops such as, “a lack of funds and resources to upskill workers” (R2), “perpetuating knowledge gap” (R3), “low adoption reinforces a lack of experience and infrastructure for change” (R6) and “low evidence for tech adoption success” (R7) are strong enough to delay the movement toward modern methods of construction. In this world, onsite manual processes are unlikely to change.

However, in this scenario, large investments in AI can’t help but impact the AEC industry in other ways. Upstream ‘knowledge work’ is accelerated (B3) by the introduction of AI design tools like

building information modelling (BIM). Repetitive design tasks are automated, but new challenges are created. For example, upskilling staff in critical thinking skills and evaluative processes to reduce the risk of AI hallucination errors. Unfortunately, the acceleration of upstream services is not enough to reduce the cost of building homes. Unaddressed reinforcing loops like a “self-perpetuating lack of diversity” (R1) means the availability of skilled workers remains low, negatively impacting the ability to deliver projects on time and under budget (R8). In response, there are attempts to disrupt the industry (R5). However, the introduction of new digital applications only fragments the suite of tools further, leading to information inconsistencies (R8), increased administrative tasks and licencing fees.

5.3.2 Scenario 2 (plausible) - Government backs pre-fab.

This scenario (Figure 6) uses the idea of a system under government ‘discipline’ [11] to imagine a future where pre-fab becomes the norm, aided by government policy. In this future, the government takes extreme measures to support the growth of prefabrication work in off-site warehouses. Doing so circumvents existing issues that heighten the perceived risk of technology and process adoption (R4, R5, R7). Government-backed investment in specific technologies and education also aims to ensure the streamlined technology adoption by circuit-breaking the “perpetuating knowledge gap” (R3), “lack of funds and resources to upskill” and “siloeed tech and work processes”.

In this future world, there are more job opportunities for people with different abilities and skill levels, which takes the pressure off demand for skilled workers (R8). A steady flow of contracts and available workers offsets the cost of technology investment required for prefabrication work (R8). The controlled warehouse environment supports incremental improvements, minimising waste, over-ordering, and improving project efficiency. However, a drastic shift toward prefabrication is not without its challenges. Although the government provides opportunities for reskilling and education, off-site manufacturing is not for everyone. Those who love the outdoors, highly tactile or creative work may consider switching industries, further reducing the number of workers with traditional skills (R8). This could negatively impact the ability to pass on tacit learning experiences in traditional skill areas, leading to issues in end product quality and safety. In addition, on-site assembly presents its own challenges, such as transporting larger materials, particularly in volumetric prefabrication.

5.3.3 Scenario 3 (plausible-possible) - Everyone a subcontractor.

In this scenario (Figure 7), the system is ‘transformed’ [11] and everyone in the AEC industry becomes a subcontractor in this plausible-possible future. Pulling this lever highlights some of the subcontracting challenges in the system. One of the obvious challenges of subcontracting is the uncertainty around who will pay workers’ superannuation, sick leave and other fair work benefits (RS5). Scenario 3 suspends this challenge, moving beyond it to explore the benefits and risks in a world where worker benefits are guaranteed by the subcontracting platforms.

Whilst there may be some deleterious effects, there are some clear positives in this scenario. Subcontractors are more likely to stay in the industry, as they feel supported to live a balanced life and do their best work. They have the flexibility to manage their work



Figure 5: Scenario 1: Describes a probable future where AI impacts the AEC industry, albeit for upstream services like architecture and engineering only. This scenario speaks to the importance of awareness and education, critical thinking skills and a cohesive approach to technology implementation, one that considers adjacent issues like the need for information interoperability, workforce diversity and a desire for physical, outdoor trades.

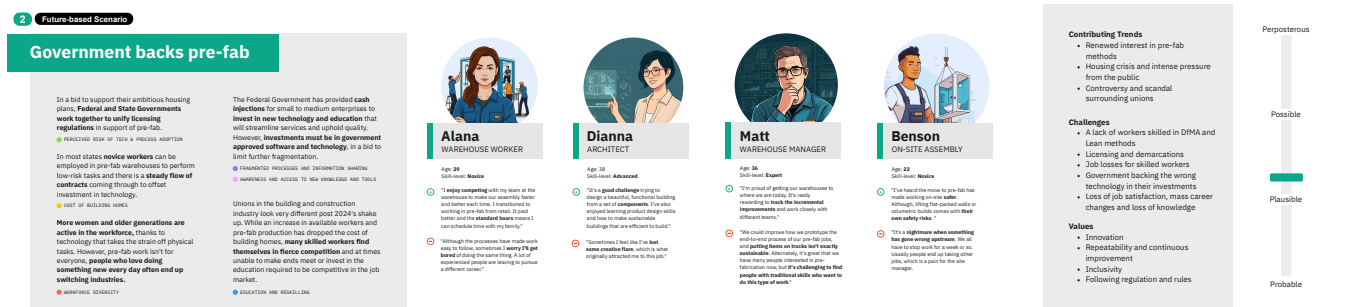


Figure 6: Scenario 2: Describes a plausible future where the government brings in policies to back prefabrication methods of construction. This scenario captures the blockers for prefabrication, such as perceived risk of technology investment and access to education, as well as the benefits and risks involved.

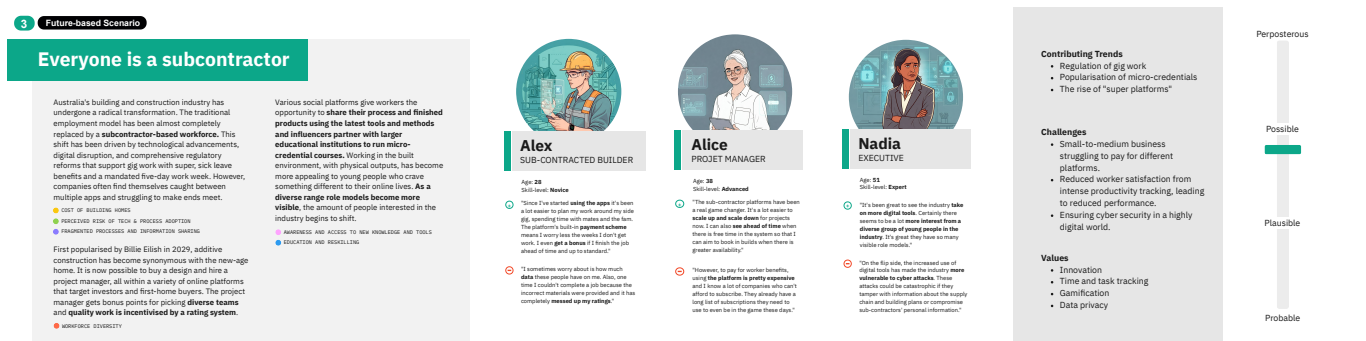


Figure 7: Scenario 3: Describes a plausible-possible future where the industry is transformed and everyone is a subcontractor. This scenario suspends present day challenges for worker benefits and helps the reader to imagine alternate pros and cons of a world where subcontracting is the norm.

schedule around their home life and can know ahead of time if a job is ready for their services or what the availability of workers is for their project (R8). The movement to digital also attracts a younger audience accustomed to managing their lives through digital platforms (RS2). However, this transformed world also comes with its risks and limitations. In particular, the reinforcing loop "siload

tech and work processes" (R8) in theme 6 "interoperability and information sharing" is heightened (RS6). The variety of platforms, along with ever-changing teams and workers, makes it even more challenging to maintain information continuity during projects. To improve accountability, the platforms introduce rating systems, which create new power imbalances between workers seeking good

ratings and their contractors. While the decentralisation of home building gives customers greater cost-effective flexibility, it also leaves them more exposed to risks without appropriate specialised knowledge in building codes and processes.

5.3.4 Scenario 4 (possible) - Climate crisis and global conflicts force change.

Scenario 4 (Figure 8) imagines the AEC industry under ‘collapse’ [11], where climate change and global conflict completely disrupt the ability to create and maintain the built environment. In this world, climate change and global conflict make it nearly impossible for the system to function in its current form.

In this state of emergency, many of the current reinforcing loops are circumvented. For example, feedback loops (R4, R5, R7, B2, B3) in external forces for change (RS5) would likely shift since the adoption of new processes and technology becomes imperative for maintaining and building homes to keep people safe and healthy. The cost of building structures (RS1) would likely become so inflated that the system has no choice but to find innovative ways to upskill people and find new ways to build and maintain homes more cheaply. Challenges with workforce diversity (R1) become almost irrelevant since anyone who can help in this disaster situation will.

Using scenarios to place key aspects of the system into alternative futures allowed us to interrogate how feedback loops might be reinforced or altered. This provided macro-level insights into the system, which we used to create speculative probes that critique various approaches to change. For instance, Scenario 1 explores the challenges the AEC industry could face if it continues along its current path while becoming increasingly influenced by AI. It demonstrates how, without educational support, the introduction of more digital tools could diminish quality and exacerbate the skills gap, further damaging the system. By projecting how the system operates today into the future, we can identify potential areas for critique in the [micro, future] phase.

These future-based scenarios were developed collaboratively with stakeholders, a key element of the project. While the speculative probes in [micro, future] were created by designers, they were largely informed by the scenarios developed through industry collaboration. This approach helped balance the top-down nature of speculative design with the recognition that designers bring valuable tacit knowledge and skills essential to carrying it out.

5.4 Instantiate [micro, future]

The future-based scenarios informed a series of speculative probes, developed by the academic team. Each scenario had two probes. These probes served as micro-level instances of the scenarios, incorporating speculative characteristics that provoke critical reflection.

5.4.1 Speculative Probes for Scenario 1 (Artificial Intelligence (AI) Pushes Innovation, For Some).

The first probe NextCraft (Figure 9 left), is an augmented reality (AR) device that can be attached to a pencil. It captures the juxtaposition of valuing the tangible aspects of a trade’s craft and the pressure from outside forces to automate and digitise work. The pencil can be used to draw, measure and visualise building

plans on handcrafted materials, while the AI attachment uses computer vision and voice activation to make work processes faster and document how materials have been installed.

The second probe GEN4BUILD (Figure 9 right), is a prompt engineering resource for architects and engineers. It speaks to current views that upstream knowledge work is an obvious area where AI will probably automate tasks and compensate for more challenging areas to automate, such as on-site work. However, mistakes in how the building is visualised capture the potential for AI to hallucinate and get things wrong. The artefact asks how the desire for speed will impact architecture and engineering, and what checks and balances may be needed.

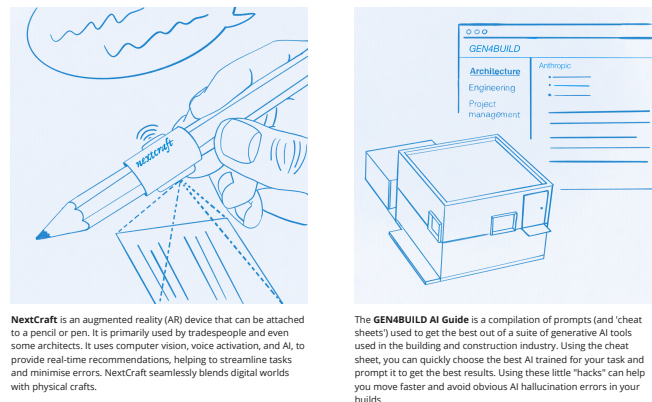


Figure 9: Scenario 1 Probes - NextCraft (left) is an AR and AI device that can be attached to a pencil and used by trade workers onsite. GEN4BUILD (right) is an AI Guide, a prompt engineering cheat sheet for architects and engineers.

Participants in the participatory workshop (n=3 of 11) felt the probes made them consider values such as safety (P2), efficiency (P1, P3), quality and error minimisation (P1, P2), maximising the potential of technology (P2) and interoperability (P3). Interestingly, interoperability was not a value we intentionally sought to reflect in the probes. The stakeholders viewed the probes as both desirable and undesirable. P3 highlighted concern that AI would erode traditional skills and creativity.

P3: “Undesired: general deskilling in traditional [techniques] [...] and [it will] theoretically stymie creativity and innovation.”

They noted the changes depicted are “underway” and “inevitable”, which validates the probable world in scenario 1 if the system were to continue on as-is and relatively unchanged.

P2 raised concerns that AI would increase distrust in technology and said the probes would be undesirable “[...] if the speed of solutions doesn’t keep up with change [in the industry]”. By this, they mean a mismatch between the AI solutions available and the way industry fundamentally operates, which has been a sticking point for the implementation of digital technology in the past. Conversely, P1 noted many desirable aspects of the probes.

P1: “Desirable! better design, improved efficiency, improved outcomes (energy, carbon, circular economy)”

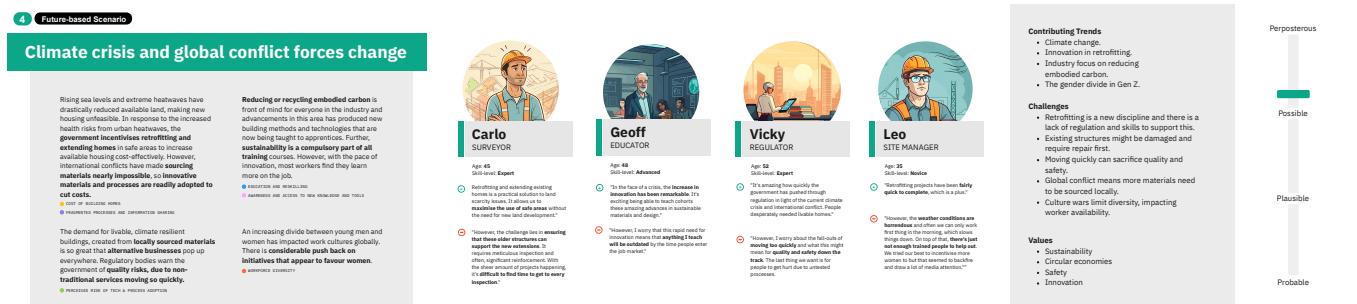


Figure 8: Scenario 4: Describes a possible future where climate change and global conflict have reached an apex, completely disrupting the ability for workers to create and maintain the built environment. This scenario situates the reader in a environment where actors have adapted to a system in collapse and extremes as the new normal.

P2 also noted that the probes were desirable since they had the potential to “attract younger generations into the industry”, which speaks to the current challenges faced with a shortage of skilled workers.

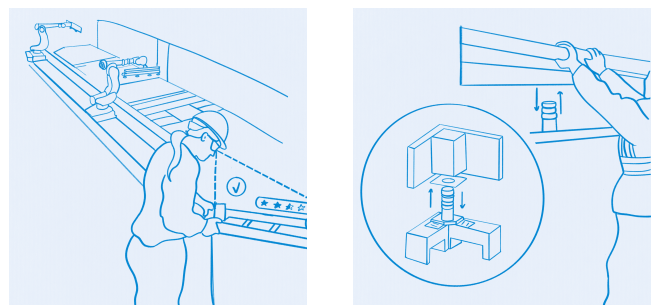
When tracing how the world would change in response to the probes, participants mostly responded to AI as a collaboration partner. P2 noted that education would need to cover “error checking” and “critical thinking”. Similarly, P3 believed that there would need to be a stronger focus on “design management”.

5.4.2 Speculative Probes for Scenario 2 (Government Backs Pre-fab).

The first probe *Lean On* (Figure 10 left) is a projection game that aims to stimulate workers in a prefabricated environment. The probe shows a female worker and robots, seeding a dialogue about who will staff these off-site warehouses. It also comments on an existing sentiment that a move to off-site manufacturing-style construction will remove the kind of craftsmanship and problem-solving involved in traditional on-site jobs. In other words, people fear this work will be boring. However, *Lean On* brings to light a different type of problem-solving encouraged by Lean production, where workers aim to improve their approach over time and find better ways to complete a task. The projection game asks what might happen if this approach to problem-solving is brought front and centre. Of course, this attempt at positivity could be cast in a dystopic light if workers are encouraged to be efficient at all costs.

The second probe *Click-in Parts* (Figure 10 right), shows what the assembly of a building might look like onsite in a fully prefabricated world. It conjures past experiences viewers will likely have of building Ikea furniture. On Reddit, there are those who view the modular approach as a fun activity or “Lego for adults”⁴, which tellingly is also published on the r\ “unpopular opinion” page. This assembly approach intends to raise questions about what processes and policies will look like. Of course, there are building companies that already do this kind of assembly work, but how will their knowledge and best practices be utilised if we were to mandate production tomorrow?

⁴https://www.reddit.com/r/unpopularopinion/comments/v2oh5a/building_ikea_furniture_is_fun/



Lean On is a projection game that aims to stimulate motivation in pre-fab construction work. It has two settings that you can choose from, *personal best* and *explore*. In *personal best* mode, you can compete with yourself or others to get the best possible time and quality rating for your construction task. Alternately, in the *explore* mode you can follow a new challenge every day and enjoy a variety of different problems to solve. *Lean On* has opportunities to level up no matter how you prefer to work.

Click-in parts makes pre-fab assembly easy. Inspired by Ikea, you can use these parts in your prefabricated construction to streamline and simplify the materials needed for assembly. With a specific set of standardised parts, it is easy to find replacements, disassemble and recycle buildings.

Figure 10: Scenario 2 Probes - *Lean On* (left) is a projection game built to motivate workers for offsite work. *Click-in parts* (right) illustrates the modularity of onsite assembly work in a prefabricated world.

Participants in the participatory workshop (n=3 of 11) felt the probes helped them consider the following values: personal development (P4, P5, P6), ease of assembly (P4, P5), creativity and problem solving (P6).

Desirable aspects of the probes included ease of assembly and replacement of parts (P6), as well as improved mental health, job satisfaction and career development (P5). However, undesirable aspects included a push back on the ‘creativity’ that *Lean On* aimed to provide. Stakeholders felt that there would be alienation of highly skilled workers who might feel “sidelined” by the production process (P4, P6). There was generally a concern that this alienation would reduce the pool of available workers and those with highly specialised skills.

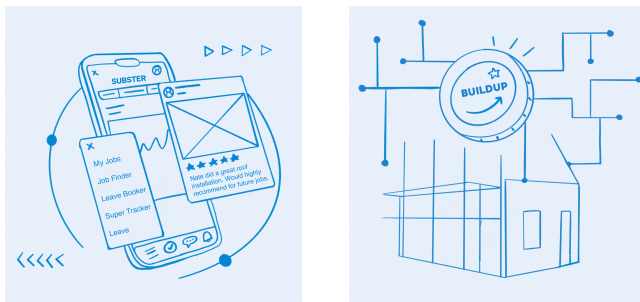
P4: “3 of 4 workers [will] find these processes beneficial”

This reflection corresponds to current concerns about a shortage of skilled workers. If people do not find the work engaging then it may be difficult to retain and attract talent in the future.

5.4.3 Speculative Probes for Scenario 3 (Everyone is a Subcontractor).

The first probe *Subster* (Figure 11 left) is a subcontracting platform that allows workers to find work and streamline their jobs. People can gather ratings on the platform as a form of self-marketing and trust-building. Although this kind of platform is not particularly new, its underlying questions about how work processes and policies in the AEC industry might change if these types of platforms are adopted at scale are interesting. In an industry with even more intense fragmentation, how do people pass on information about a project? Does this move to ultra-lean businesses really mean more time spent trying to share information about a project with even more parties?

The second probe *BuildUp* (Figure 11 right), is a blockchain protocol that allows workers to invest in their project. Workers earn tokens that are tied to a small percentage of the building's value. These tokens contribute to their retirement benefits. Although they are a small percentage of the building, these add up over time. Quality work increases the value of the house and therefore the value of the tokens, incentivising a level of care, as though it were their own home. It calls for a reflection on what encourages people to produce quality work.



In a world where everyone is a subcontractor, "getting on the apps" is essential. Being on a subcontracting platform, like *Subster*, means you have the security of being paid, taking leave and managing your jobs. Walking on site and knowing what needs to be done is easy, no more wasted time arriving when the site isn't ready for your work yet. Project managers and customers can give you a rating for different skills, which helps you stand out (or not).

It is now possible for expert tradespeople to collect *BuildUp CryptoTokens* as they work on different projects. These tokens offer a small percentage of ownership over the final building and continue to accumulate wealth throughout the life of the construction. It's an opt-in scheme and a promising way to diversify your superannuation. You can watch your tokens build up through the app and cash them in when you retire. It's rewarding to know that what you're building is an investment in your future.

Figure 11: Scenario 3 Probes - Subster (left) is a phone application that is a must-have for people working in building and construction. BuildUp CryptoTokens (right) allows workers to earn income for their retirement.

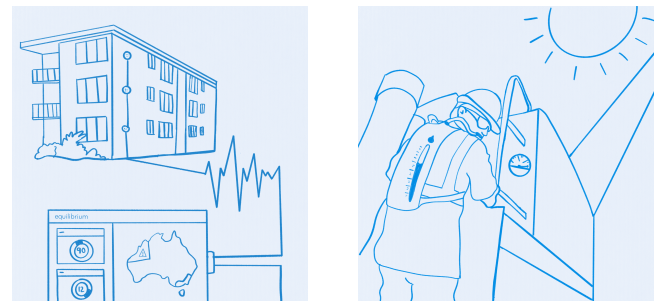
Participants in the participatory workshop (n=5 of 11) felt the probes captured several values, including: self-motivation (P7, P8), pride (P2, P7, P8), individuality (P2), and traceability (P3, P2, P7, P8, P9).

Desirable aspects of the probes included the ability for people across the AEC industry to monitor the progression of a project so that they can predict when there will be delays, this includes managers and onsite workers (P2, P7). This emphasises the need for better tracking systems to ensure jobs are completed on time. Conversely, undesirable aspects included disjointed applications that make work more challenging (P8) and inefficiencies for coordination if everyone is a subcontractor (P7).

5.4.4 Speculative Probes for Scenario 4 (Climate Crisis and Global Conflict Build).

The first probe *Equilibrium* (Figure 12 left), is a government-backed program for monitoring the energy performance and overall health of retrofitted homes. It brings into question the role of Government in housing and maintenance, being positioned to ask who has access to data about homes and who the obligation to maintain these structures sits with. It also poses questions about home retrofitting and what quality looks like in this space.

The second probe *SafeGear* (Figure 12 right), describes workwear that helps people carry out tasks in extreme conditions. It aims to pose questions about the future of work as climate conditions worsen.



Equilibrium is a government-backed program for monitoring the energy performance and overall health of retrofitted homes. You can now live in comfort knowing that your home is delivering the best possible insulation, energy and humidity levels for extreme climate conditions. If your retrofit shows signs of poor quality then a consultant will assess your home and schedule cost-effective fixes for common issues. Maintenance is easy since the house has been built for upgrades.

Working outside is near impossible in extreme weather conditions but thankfully *SafeGear* workwear and tools help people cope. Working outside is still a challenge but made bearable by anti-heat clothing and easy access to water. Safety protocols include ensuring that people take breaks under the shade and checking that machinery is not overheating.

Figure 12: Scenario 4 Probes - Equilibrium (left) is a government program for monitoring retrofitted homes. SafeGear (right) is a wearable for extreme working conditions.

Stakeholders in the participatory workshop (n=5 of 11) felt the probes captured several values, including: healthier homes (P5, P11, P13), health and safety of workers (P3, P11, P13), and, of course, sustainability (P5, P13).

Desirable aspects of the probes included a need to address climate change issues and new innovations in technology to support this. Additionally, participants talked about a desire for healthier homes and a focus on safety for workers. Conversely, undesirable aspects included a drop in quality due to a need for rapid innovation (P3, P5, P13) and the potential that education might struggle to keep up with this pace in the current schema (P13).

5.5 Reflect [micro, present]

By clustering desires and concerns in relation to the speculative probes and comparing them with clustered themes relating to the leverage points in the systems map, we identified three core **systemic futures tensions**. These tensions are a novel output of the Systemic Future Dialogue, generated from the orchestration of systemic and speculative design across micro–macro and present–future dimensions. By moving between these levels, the process identifies contradictions and trade-offs between systemic change solutions and desired futures. This enabled participants to critically visualise and assess how seemingly appropriate changes may reinforce undesirable system dynamics over time.

- (1) **Productivity and Job Satisfaction:** The AEC industry faces pressure to improve productivity due to a shortage of skilled labour and high costs, as one participant explained “[...] *saving usually must be in speed/labour reduction (variable costs)[...]*”. However, the push for greater efficiency may conflict with the industry’s desire to create fulfilling jobs that keep workers engaged. It was specifically called out that an undesirable aspect of the probes was a lack of creativity, innovation or uniqueness in the tasks being carried out. This tension raises an important question: **what would it take to improve productivity while also creating satisfying jobs that people feel are fulfilling to carry out in the long term?**
- (2) **Modern Methods of Construction and Preserving or Augmenting Traditional Skills:** Modern methods of construction (MMC) create new opportunities to recruit a diverse workforce. For example, robotics that make heavy lifting easier for women, the older adults, or people with physical disabilities. However, there is tension between embracing innovation and preserving traditional skills, often driven by concerns about the cost of adapting to change. As one participant pointed out, they did not want to “[contribute to a] *further accentuated skill gaps as well as “deskilling”*”. This calls into question how the AEC industry will bridge the gap between innovation and preserving or augmenting traditional skills: **which skills must be safeguarded to maintain quality, and what might happen if we design with the human cost of technological change front of mind?**
- (3) **Pace of Innovation and Safety and Quality:** There is a strong push to encourage innovation, but this creates tension with the time required to uphold quality and safety; both are essential for a healthy and desirable future. Alternatively, as one participant pointed out, “*rapid innovation may render existing training programs obsolete, creating a disconnect between education and industry demands*”. This poses the question: **how might quality and safety keep up with innovation, and how can education help lead the way?**

These systemic futures tensions are useful in focusing design efforts and structuring a research and innovation agenda. They are grounded in real-world trade-offs and challenges articulated by industry stakeholders. In addition, the tensions offer an accessible way to reflect and critically evaluate possible futures that might otherwise be too alien or too technocentric.

6 LIMITATIONS AND FUTURE WORK

While this work contributes novel insights through the design artefacts we co-created with industry, our approach, generating knowledge by *doing* design, has its limitations. First, we did not directly compare or evaluate our approach against alternative methods. This was not feasible within the scope of a project shaped by predefined goals, timelines, and available resources. Further, it is inherently challenging to identify a process or framework with similar scope. Now that we have articulated this framework, future research is well positioned to systematically compare and contrast it with other approaches.

Second, there are aspects of our process that we would approach differently if given the chance to revisit the design work. While it remains difficult to determine whether these changes would have yielded different outcomes, this is not the central aim of our contribution. For instance, we identified leverage points and desirable/undesirable futures in the same workshop. With the benefit of hind-sight, we would have identified leverage points during the *model* phase (stage 2 in Figure 2) and the desirable/undesirable futures during the critique phase *critique* (stage 4 in Figure 2). These improvements could have only been realised once we were able to critically reflect on our experiences. We were also restricted by timing, typical of industry-based research, where busy participants are asked to contribute to the research with in-kind hours. For this reason, we combined the identification of leverage points and desirable futures critique in the same workshop. However, we do not believe this had a significant impact on the results, since we validated the systemic design tensions with industry representatives, providing an opportunity to check the workshop outputs.

Finally, while we made a concerted effort to include diverse voices from across the architectural, engineering, and construction (AEC) sectors, we acknowledge that it was not possible to capture every perspective. Broader industry representation was constrained by factors such as time, scale, and resource limitations beyond the control of project team.

7 DISCUSSION

The Systemic Futures Dialogue offers a new structured orchestration and epistemological contribution to futuring work [52], exploring imaginings of technological futures that “takes the messiness of everyday life as a central theme” [7, p.133]. It bridges present-day insights with speculative futures, tracing the golden thread that connects immediate challenges to long-term possibilities. The dialogue’s participatory, systems-oriented approach enables stakeholders to move between detailed problem areas and broader systemic perspectives, creating speculative artefacts grounded in real-world concerns. We conceptualise **systemic futures tensions**, a novel output that allows researchers to identify conflicting values in near and distant futuring. By unpacking key moments in the process, we demonstrate how this approach navigates the balance between designing *with* and designing *for* participants, and how it acts as a catalyst for critical reflection within complex industry contexts.

7.1 Grounding speculative work in participatory and present-day insights

The **Systemic Futures Dialogue** provides a structured pathway between what we know about the world today and desires for the future. It grounds speculative futures in real, observable trends, ensuring that imagined scenarios remain connected to current realities. For example, by tracing the process across the dialogue, we see how early discovery insights, such as the shortage of skilled workers, informed the development of a systems map that illustrated how a fragmented technology landscape could exacerbate these shortages. Viewing these interconnected challenges at a macro level allows us to extrapolate and imagine how the future might unfold under different conditions. For instance, if climate change and global conflict forced widespread reskilling, we could imagine how education

systems might adapt or explore new methods of skill development through speculative probes. Looking back from probes like *LeanOn*, we see how tangible problems, such as the skilled labour shortage, directly shaped this design artefact. This approach responds to earlier criticisms that speculative design processes can feel vague or disconnected, providing industry stakeholders with a clearer, more traceable link between present-day issues and imagined futures.

7.2 When to *design for* and when to *design with*

Design futuring methods have the potential to help organisations critically reflect on their strategic plans [61]. However, using critical design futuring in participatory settings presents challenges. These methods rely on experience and tacit knowledge that can be difficult for novices to acquire, and they may feel disconnected from the predictive, goal-oriented approaches to future planning that industry experts are familiar with. Conversely, taking a purely top-down approach risks imposing a narrow perspective that overlooks stakeholders' experiences and valuable insights. In this work, we demonstrate an alternative path, showing how participatory activities can generate the data that informs design futuring artefacts. While the final speculative probes were not created directly by the industry stakeholders, participants could see their input reflected in the themes and narratives that emerged throughout the engagement. This approach invites reflection on when we choose to *design with* rather than *design for* and how these can be used in complementary ways.

7.3 Systemic futures tensions as circuit breakers for feedback loops

An important feature of the Systemic Futures Dialogue is its ability to guide researchers and participants between micro and macro perspectives, creating a dynamic process of zooming in and out. As discussed earlier, this movement not only helped to progressively build alternative futures grounded in present-day observations but also revealed how unintended consequences can emerge when focusing too narrowly on a single problem area. For example, while incentivising (or even mandating) the use of certain tools might be intended to drive their adoption, stepping back to view the system through future-based scenarios shows how, without equitable access to resources, such interventions could ultimately do more harm than good.

The final systemic futures tensions act as circuit breakers for reinforcing feedback loops. They prompt industry participants to question the underlying tensions between pragmatic solutions in the present and their aspirations for the future. This process helps participants critically reflect on current priorities while keeping one eye on the kind of future they want to create. For example, while the AEC industry faces mounting pressure to build more homes and increase productivity, speculative probes surfaced another priority: job satisfaction. Most participants agreed that meaningful, satisfying work remains vital. In this way, the dialogue re-centres the research agenda around the apparent paradox of productivity and supporting long-term human satisfaction and wellbeing. These were conversations led by industry participants and offered as the focus of the next phase of research [60].

These tensions offer a novel output from our approach, generated specifically from the orchestration of systemic and speculative design activities across micro–macro and present–future dimensions. This enables participants to examine how, at times, abstract interventions at the macro level materialise as concrete technologies and interactions at the micro level. Rather than producing only solution-oriented outputs, the approach makes visible how seemingly appropriate changes in the present may reinforce undesirable system dynamics over time. This provides a distinct advantage over existing methods or systemic and speculative design as individual activities, by enabling participants to critically evaluate the long-term material implications of change within a sociotechnical system.

8 CONCLUSION

In this paper, we introduced the **Systemic Futures Dialogue**, a structured orchestration of speculative and systemic design methods. Developed through close collaboration with the AEC industry, this dialogue asks design practitioners to observe, model, extrapolate, critique, and reflect across micro and macro perspectives, using each step to inform and deepen the next. By doing design *with* and *for* stakeholders, we were able to preserve the critical and imaginative strengths of speculative design while making its outputs accessible and actionable for an industry audience. The output of this orchestration is a set of **systemic futures tensions**, which we conceptualise as a novel output that captures the trade-offs between short and long-term desires. These tensions show how organisations can critically reflect on whether their present-day innovations align with their aspirations for the future, and invite them to reconsider how they design and implement technology within complex systems.

Looking forward, we see the **Systemic Futures Dialogue** as a foundation for future research that deepens empirical inquiry into **systemic futures tensions**, expands participatory engagement across more diverse stakeholders, and explores how this approach can be applied in other industry contexts. By offering a pathway to navigate the ontological and epistemic differences between speculative and systemic design, we hope this work inspires others to experiment with, adapt, and extend the dialogue and conceptual outputs to support more reflective and collaborative innovation.

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A APPENDIX

A.1 Industry Participants

A.2 Systems map of the AEC Industry

ID	Gender	Years of Industry Experience	Role	Experience	Involvement in Research Steps [Yes (Y), No (N), not applicable (N/A)]							
					1	1.1	2	3	4	5.1	5.2	5.3
P1	Man	25	Director for Applied Research and Innovation	Dean faculty of Building Construction and Engineering (15 years), research including building and construction (10 years).	N	Y	Y	Y	N/A	Y	N/A	Y
P2	Man	21	Digital Strategic Partnerships Exec	Structural Engineer on multiple building types, moving to a supplier of mass timber products as design lead. Spent 10 years in a developer building mass timber buildings, and more recently in design automation software.	Y	Y	Y	Y	N/A	Y	N/A	Y
P3	Man	25	Research Development and Education Manager and Architect	Specialises in the manufacture and design of buildings made offsite using advanced methods of manufacturing. This came after spending the first 15 years finding construction generally inefficient and cumbersome.	N	N	N	Y	N/A	Y	N/A	Y
P4	Woman	10	Manager, Research and Evaluation	Working in a regulatory agency, managing licensing and registration functions, and managing the research program.	N	N	N	N	N/A	N	N/A	Y
P5	Man	25	Senior Technical Advisor - Sustainable and Future Built Environments	Sustainable Building Advisor for a Peak Body for the past 20 years and worked on building and construction related projects and research for the last 24 years. Extensive experience in education and training has informed the development of nationally recognised sustainable construction training programs. Extensive experience working with regulator organisations.	Y	Y	Y	Y	N/A	Y	N/A	Y
P6	Prefer not to say	9+	Chief Analyst	Worked 9+ years for a regulator as their chief analyst.	Y	Y	Y	Y	N/A	Y	N/A	Y
P7	Man	11	Prefabrication Leader	7 years as an engineering then remaining time in current role.	N	N	N	N	N/A	Y	N/A	N
P8	Man	11	Business Analyst	Prefab Manufacturing for mostly residential Construction.	N	N	N	N	N/A	Y	N/A	N
P9	Man	14	National Engineering Manager	Previously worked as a consulting structural engineer in the buildings space. Now have moved into an engineering lead role at BlueScope steel in manufacturing of composite metal decking.	N	N	N	N	N/A	Y	N/A	N
P10	Man	35	Consultant	Engineering and construction, experience working for large construction companies.	N	N	N	N	N/A	Y	N/A	N
P11	Man	40	Director of Innovation	Director at a large building services company with a background in mechanical engineering	Y	Y	Y	Y	N/A	Y	N/A	Y
P12	Man	35	General Manager (surveying)	General manager for a consulting firm, specialised in building surveying.	N	N	N	Y	N/A	N	N/A	N
P13	Man	7	Senior Research Advisor	Leads research at a regulatory body, with an extensive history in regulatory agencies.	Y	Y	Y	Y	N/A	Y	N/A	Y
P14	Man	12	General Manager (prefabrication specialist)	General Manager of a large international wood products company. Has a background in car manufacturing (an additional 17 years of experience).	Y	N	N	N	N/A	N	N/A	N
P15	Man	26	Research Director	Research director of a large cross-disciplinary research centre specialised in building and construction. Was trained and practiced as an architect before moving into academia.	Y	N	N	N	N/A	N	N/A	N
P16	Woman	17	Policy and Industry Collaboration Advisor	Policy advisor for sustainability in the building and construction industry. Trained and practiced as an architect.	Y	N	N	N	N/A	N	N/A	N
P17	Man	38	Emeritus Professor of Construction Management	Experience across trade and senior management positions in design, construction, estimating, project management and professional consultancies.	Y	N	N	N	N/A	N	N/A	N

Figure 13: Participants and their involvement in each step of the case study (see Figure 2)

