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# ARCS OF IMPACT

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## **Towards systemic participatory prototyping of interactive software**

**Haochen Gao, Catherine Letondal, Sylvain Pauchet, Ines Di Loreto, Rob Vingerhoeds**

With several planetary limits being exceeded, the problem of the sustainability of IT systems is becoming ever more urgent. From the outset, participatory design (PD) has encouraged end-users to take control of the design of the IT tools they are to use by fostering co-designing and collaborative prototyping, but we increasingly need to attend to the wider ecological and societal influence of the systems it helps create. Systemic design (SD) has been identified as an approach that makes it possible to address issues of strong sustainability by taking into account several scales in all their complexity. This paper therefore frames the methodological question of how participatory design of software tools and systemic design might be combined in a way that keeps participatory prototyping meaningful while bringing systemic concerns into the discussion. Building on Jones & van Patter's four design levels, we discuss the use of PD tools usually meant for interventions at levels 1-2 for supporting levels 3-4 analyses. We identify two research gaps: (1) sustainability-oriented PD rarely make use of SD tools, and (2) relevant SD representations for PD may be too abstract for end-users immersed in contextual prototyping. An exploratory use case provides an initial probe. Five researchers co-created a prototype of a digital travel diary during a workshop and later revisited the concept analyzing rebound effects and causal loops. The insights from these workshops show a potential to inform the design of future workshops where systemic prompts will be included from the start. We contribute two aspects: (1) a level-based perspective that identifies research gaps with respect to methods and tools, and (2) a first exploration, based on a workshop, offering insights into emerging perspectives. Together, these findings outline next steps for developing systemic participatory prototyping at multiple scales.

**KEYWORDS:** participatory design, systemic design, sustainability, human-computer-interaction, software tools, methodology.

**RSD TOPIC(S):** Mapping & Modelling, Methods & Methodology, Sociotechnical Systems

## 1. Introduction

Participatory Design (PD) has long been valued for involving end-users in the co-creation of digital products and services that shape their daily lives. These projects rely heavily on end-user engagement into co-design of interactive tools, which includes producing concrete representations of user interfaces (UI) through prototyping and mock-ups, anchoring co-design exploration in the context of their own experience of interacting with tools in their activity.

The project discussed in this paper takes a strong sustainability stance, treating planetary boundaries (Steffen et al., 2015) as hard constraints for design, and it addresses how to include strong sustainability concerns in a PD project that involves end-users of interactive tools. Sustainability-oriented PD has broadened agendas yet seldom brings structured systems analysis (e.g., feedbacks, rebound) into workshops. Systemic design (SD) brings systems thinking into design to address such complexity, which is why we reflected on how a systemic design approach may help in this regard. However, SD offers relevant analyses but rarely cross-references PD's hands-on prototyping practices for interactive digital products (Jones, 2017; Jones & Van Ael, 2022). This asymmetry motivates our question of how to adapt systemic methods for end-user participatory prototyping while building on PD's strengths. Building on Jones & van Patter's four design levels (Jones & van Patter, 2009), we discuss the use of PD tools usually meant for interventions at levels 1-2 for supporting levels 3-4 analyses, and the use of SD tools usually meant for interventions at levels 3-4 for supporting levels 1-2 participatory prototyping methods.

In particular, we have identified two methodological difficulties. While traditional participatory prototyping excels at engaging end-users to create concrete, local solutions such as new digital products or services, its customary focus, and its strength, remains the immediate context of use. The first difficulty is therefore: how to introduce into a participative prototyping workshop methods addressing systemic concerns, and tools such as system maps, causal-loop diagrams, to reveal relationships and root causes across systems, without losing the needed anchorage in the context of use? Second, some SD methods that we think are relevant for our needs, such as modelling of system dynamics, are typically expert-driven and, for many end-users, may be hard to grasp—especially when unfamiliar diagrammatic representations are employed.

We illustrate our point with a case study that addresses strong sustainability in transportation, focusing on the levels of the design in interactive applications. This case study indeed illustrates why systems thinking is critical: without it, even well-designed

local innovations risk overlooking root causes, missing sustainability objectives, or triggering unintended long-term consequences.

Our research question is thus: How can systemic design methods be adapted for end-user participatory prototyping workshops? In this paper, we contribute two aspects: (1) a level-based perspective that identifies research gaps with respect to methods and tools to address this question, and (2) a first exploration, based on a workshop, offering insights into emerging perspectives.

The paper is outlined as follows: a first related work section provides a summary of participatory design (PD) and participatory prototyping in human computer interaction (HCI), current trends in sustainable participatory design, and a brief description of systemic design (SD) tools and methods that would apply to our case study ; section 3 then specifies PD and SD traditional levels of analysis and interventions according to Jones & van Patter (2009) framework; in section 4, we discuss how PD and SD can be extended beyond their primary levels. Section 5 presents the case study. The paper ends with a section outlining a few perspectives.

## **2 Related Work: Participatory prototyping and Systemic design approaches**

In the following sections, we briefly describe the core principles and methods of PD and SD.

### **2.1 Participatory Design**

Participatory Design (Greenbaum & Kyng, 1991; Bratteteig & Wagner, 2016; Schuler & Namioka, 1993) has its origins in the Scandinavian efforts of the 1970s to democratise digital technology design by involving workers in shaping the computer systems that structured their jobs. It was rooted in early human-centered design (HCD) concept but pushed further to actively involve users as co-designers. Importantly, HCD itself grew out of the emerging field of Human-Computer Interaction (HCI): early concerns were about the design of user interfaces and interactions with computers and also how human capabilities and organizational realities should shape its development. Researchers in the early 1980s noticed that interactive systems built solely by programmers often failed because users had to adapt to the technology rather than the other way around (Gould & Lewis, 1985). Conceived as a corrective, HCD foregrounded the needs, abilities, and limitations of the users and their direct interaction with computers, laying essential groundwork for participatory ideals.

The evolution of PD is often framed in terms of HCI's "three waves." First- wave HCI (1980s) focused on individual users and cognitive performance and gave birth to PD in work settings. Second- wave HCI (1990s) expanded to group work, CSCW (Computer Supported Cooperative Work), and context; during this period PD became an established method using refined techniques such as in- situ workshops and prototyping for eliciting end-users' needs. It also included the analysis of organizational dimensions to design tools in a more relevant way, that would be aligned to the co-evolution of practices based on end-users' priorities, problems and values. Third- wave HCI (2000s onward) extends into everyday life and heterogeneous contexts, addressing experience, emotion, and societal domains. PD projects have correspondingly expanded beyond the workplace, becoming "increasingly engaged in public spheres and everyday life" (Björgvinsson et al. 2010).

A key feature of PD is its emphasis on participatory *prototyping*. Early pioneers introduced the idea that shifting "from prototyping by demonstration to cooperative prototyping" allows users to shape design ideas actively, rather than merely respond to them (Bødker & Grønbaek, 1991). These prototypes are generally built from low- tech materials like paper sketches and cardboard models (Figure 1). What matters is that they act as boundary objects (Huvila et al., 2017)—shared references that help participants think, communicate, and explore ideas together, and surface hidden needs through making.



Figure 1. Participants modifying a paper prototype to illustrate pain points, confusing elements and interactions. Source: Naranjo-Bock, C., n.d.

In PD, the context of use acts as a design material: design ideas must be anchored in the concrete use experiences of end- users, for example in work scenarios or data, such material being generally built up from contextual interviews (Beyer & Holtzblatt, 1998). Greenbaum & Kyng's seminal volume *Design at Work* (1991) documents numerous

cases—from newsroom layout tools to graphic- design workstations—where insight into workplace routines, artefacts, and social relations fundamentally redirected the design process.

Rather than emphasizing technical problem- solving alone, PD foregrounds the processes of decision- making and the sharing of power in design, enabling users to actively participate in creating, selecting, and evaluating design choices. As Bratteteig & Wagner note, “creating choices is fundamental to PD where all participants are invited to contribute to those choices” (2016, p. 427).

## **2.2 Participatory Design and Sustainability**

A review of the Participatory Design Conference papers (Poderi & Dittrich, 2018) identified three recurring patterns in how PD engages with sustainability: using PD to tackle sustainability challenges (PD4S), making participatory processes themselves sustainable (SPDP), and ensuring the long- term durability of PD outcomes (SPDR). For example, the Visions & Pathways 2040 project brought different stakeholders together to discuss future urban sustainability through workshops and scenario building (Gaziulusoy & Ryan, 2017). Similarly, Chopra et al. (2022) used speculative participatory workshops to connect everyday urban food-growing in personal gardens with larger national policy and infrastructure issues, using cardboard maps and prompt cards as a space for individual expression, and speculative walks.

Recent PD projects are also engaging with sustainability through concrete co-design and prototyping of IT tools with communities. For example, Heitlinger et al. co-designed an IoT-based sensing and data-sharing toolkit with urban food-growing communities to support more sustainable city food systems, producing working probes and workshop artefacts that informed the resulting digital tools (2018). Similarly, Prost et al. worked with local food networks to prototype and trial digital resources and platforms that support “food democracy”, using situated workshops and iterative prototypes to connect everyday practices with systemic sustainability concerns (2018). These cases underline the need for methods and tools that bridge hands-on participatory prototyping with broader sustainability reasoning in PD.

In these projects, PD is effective in engaging communities and grounding sustainability in wider contexts, but does not involve tools to explore e.g. long-term effects or hidden consequences. So, PD projects have started to address sustainability as a global concern, but do not use systemic perspectives where systems thinking would help to tackle complexity. In fact, PD is rarely referenced in SD research and vice versa.

## **2.3 Systemic Design Tools**

Systemic Design emerged in the 2000s–2010s and stems from the idea of combining the approaches of complex thinking and design thinking. As designers grappled with “continuous wicked problems on a planetary scale.” (Jones, 2017), SD integrates dialogue, design, and co-creation to support sense-making and decision-making in complex arenas (Blomkamp, 2021). A defining feature of SD is its reliance on tools and representations that make complexity visible and debatable at a glance. SD indeed relies on mapping tools to frame complex issues and systems, and on relational, diagrammatic representations of dynamic behaviour—stock-and-flow models, causal-loop diagrams, actor maps, or gigamap (Sevaldson, 2015)—that render hidden feedback loops, time delays, and leverage points visible. These representations serve to externalise complexity so it can be discussed and restructured creatively.

Taken together, these precedents suggest that accessible modelling plus facilitation can coexist with PD activities and support system-aware prototyping.

### **3 Design Analysis and Intervention Levels for SD and Traditional PD**

To clarify respective objectives and methods of PD and SD, it is useful to refer to the difference between a design’s level of analysis (the scale at which a situation is understood) and its level of intervention (the scale at which a design solution is implemented) according to the framework proposed in Jones & van Patter (2009). To clarify, we also discuss the term “participation”, which alone does not differentiate between the two approaches.

#### **3.1 Design Levels 1.0–4.0**

Researchers have distinguished levels of design based on the scope of intervention—from crafting individual artefacts to shaping societal systems. One influential model is the Design 1.0–4.0 framework by Jones & van Patter (2009), which aligns roughly with Buchanan’s four orders of design (Figure 2). Design 1.0 refers to traditional craft and product design; Design 2.0 to product/service design at the system or interactive-product level; Design 3.0 to organisational transformation; and Design 4.0 to social or systemic transformation. Each higher level involves a broader scope, greater social complexity, and more abstract outcomes. While these levels are interdependent, they demand different mindsets and methods (Jones, 2014).

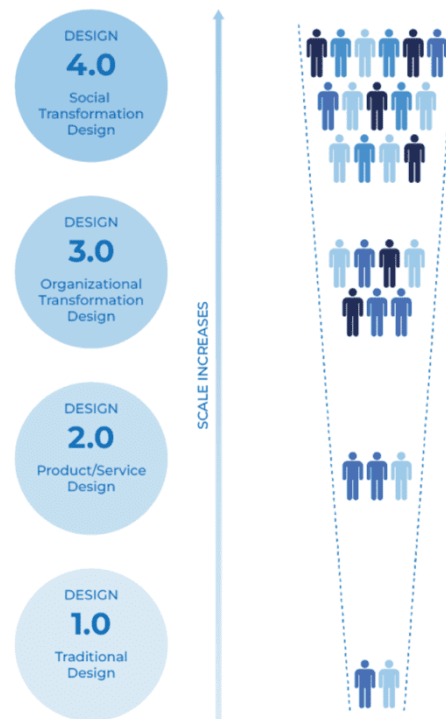


Figure 2. Mapping design process to challenge complexity (Jones, 2013).

## 3.2 Analysis and Intervention Levels in PD and SD

### 3.2.1 Analysis and Intervention Levels in traditional Participatory Design

PD interventions are on level 2.0, since PD targets the design of interactive tools and services, while it is based on analyses at levels 1 to 3, sometimes 4. In particular, level-2 of analysis is concerned with the user's context of use of IT tools, which however PD does not isolate from the organizational and sometimes political context.

### 3.2.2 Analysis and Intervention Levels in Systemic Design

SD targets intervention levels 3-4, for instance, in organisational transformation, multi-stakeholder service ecosystems, or public policy development (Jones, 2017). Using levels 3-4 analyses, practitioners employ visual system representations—such as gigamaps, causal loop diagrams, and stock and flow models to reveal feedback loops and leverage points, notably with the Systemic Design Toolkit (Van Ael et al., n.d.; Jones & Van Ael, 2022). However in practice, explicit links back to PD's Level-2 workshop practices remain limited, which is the interface this paper explores.

## 3.3 What do we mean by "participatory"?

We must be careful with the meaning of the word *participatory* because systemic design and participatory design are both highly participatory. SD invites the participation of

various stakeholders, including ordinary citizens, for the construction of representations such as actors maps, in order to help building a collective understanding of systemic interdependencies. In contrast, participation in PD emphasizes direct, concrete engagement of end-users in the making of mock-ups, leveraging their lived experiences to co-create solutions. As explained by Bratteteig & Wagner (2016), PD introduces participation into Schön's "design moves": seeing-moving-seeing (Schön, 1983), where end-users are given the opportunity to participate both in the *creation* of choices in a language that is not abstract or formal and in the *decision* about choices. They note that, because the final artefact does not yet exist, "creating representations of possible design results plays a major role"; yet once a particular representation is selected and "'locking' choices in an artefact ... can be considered an act of power", deciding which one to materialise already shapes who can influence the design that follows.

#### **4. PD and SD across traditional Levels**

It is possible to use these notions of level of intervention and analysis to identify possible areas of combination between the two approaches.

##### **4.1 Use of 1-2 Levels in SD**

In their book, "A Design Journeys through Complex Systems", (Jones & van Ael, 2022, pp 90-91), the authors show how SD uses 1-2 levels design thinking and design methods (Figure 3). Several methods that are cited as used in SD are also widely used in HCI, HCD and PD, such as ethnography, contextual interviews, case studies, usability evaluation, or ideation.

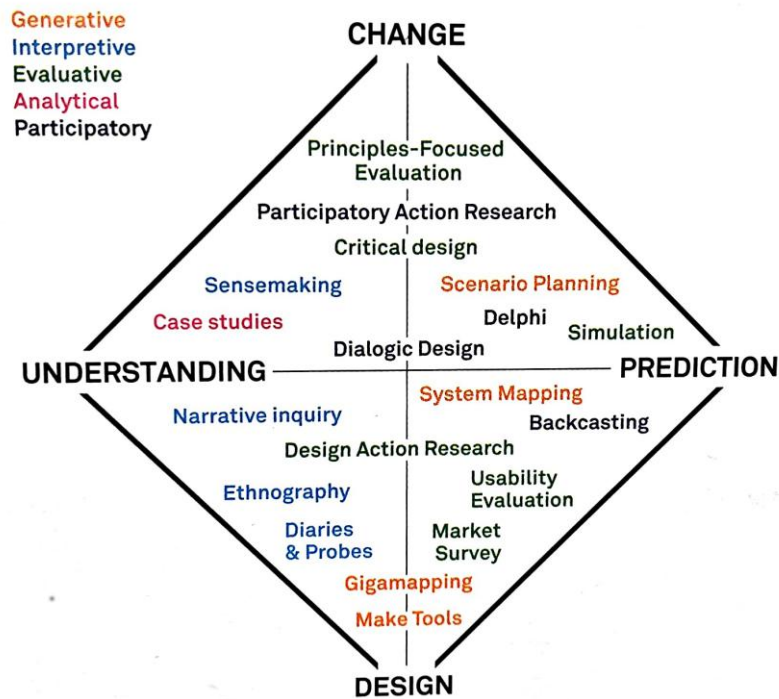


Figure 3. Systemic design methods by research intent. Source: Jones and Van Ael, 2022, p.91

## 4.2 Use of 3-4 levels in PD

### 4.2.1 Level 3 interventions in PD

PD interventions have sometimes migrated toward higher level arenas, including urban governance, climate adaptation planning, and healthcare reform, illustrating its capacity to engage with organisational and systemic transformation when appropriate scaffolding is provided (Björgvinsson et al., 2010; Hodson, Svanda & Dadashi, 2023). For instance, the *IPCity* project described in Bratteteig & Wagner, delivered a “collaborative urban mixed-reality application” that enabled planners and citizens to rehearse redevelopment scenarios together.

### 4.2.1 Levels 3-4 analyses in PD

Bratteteig & Wagner’s comparative study reminds us that PD has tackled meso- and macro-levels for analysing purposes. For instance, in the *Florence* project, nurses, through collaborative prototyping of user interfaces and forms they need, re-negotiated hospital information flows.

Recent research projects (e.g., Bornes, Letondal, & Vingerhoeds, 2023) have focused recently on the development of methods and tools to enable product and service designers (levels of interventions 1 and 2) to benefit from systemic analyses. Building on

this approach, the Magnitude software tool supports quantitative modelling of dynamic systems—a visual representation of feedback loops that maps relationships between system variables (Bornes et al., 2024). In their Vinted case study, the simplified Causal Loop Diagram reveals reinforcing loops (such as: growing user base → higher platform attractiveness → more transactions), alongside balancing loops that aim to reduce emissions through mechanisms like distance filters or seller quotas. By visualizing how small design changes can ripple through these loops, product and service design teams can quickly grasp the systemic impact of their decisions. However, this methodology was developed explicitly for professional designers, not for end-users.

#### **4.2.2 Potential problems for end-users in systemic participatory design**

PD tools, designed to elicit experiential insights, are not meant to support systemic reflection and usable tools that could empower lay participants to explore and act on systemic aspects during participatory prototyping workshops are currently lacking. Besides, end-users in PD may face distinct challenges when engaging with systemic-level analysis methods and tools (levels 3–4) and may struggle with abstract representations like causal-loop diagrams or complex feedback dynamics unless mediated by facilitators.

### **5. Case Study – The ‘travel diary’ Participatory Workshop**

This section presents the case study of a “travel diary”. We organised a small-scale, exploratory workshop with our research group, as a first step toward a broader programme of case-studies that will be conducted with end-users in subsequent project phases. Facilitated by the research team, the session had two complementary objectives: (1) exploring a prototype (the “Magic Pen”); and (2) experimenting with the application of a systemic-design analysis adapted to PD methods.

#### **5.1 Process**

Prior to the workshop, participants had collected elements that could form part of a travel diary for a trip they had actually made: train tickets, photos, messaging discussions, etc. (figure 4). Facilitators introduced the context—the need for travel diary tools that not only enrich user experience but also prompt reflection on ecological impact. Participants were guided by prompting questions (e.g. “Who is the user – a solo backpacker, a family traveller, a business traveller?”; “What challenge are they facing – tracking carbon footprint, sharing stories, reducing waste?”) to ground their ideas in real-world scenarios.

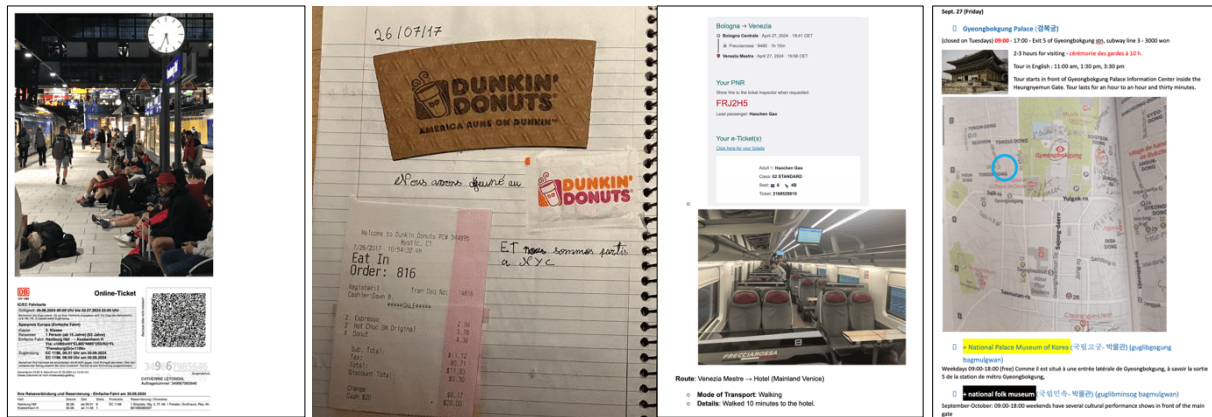


Figure 4. Travel diaries brought by participants prior to the workshop.

They first took part in open brainstorming, producing numerous rough ideas individually and in small groups (Figure 5). A rapid sketching exercise using the Crazy 8s technique was then introduced to boost creative exploration—each participant sketched 8 quick concept variations in 8 minutes. The session produced a flurry of ideas, ranging from AI-assisted travel journals to sensor-based “eco-diaries.” Participants shared and clustered these concepts, discussing their strengths in a group discussion. Through dot-voting and consensus, the group identified several promising directions. One idea stood out for its creativity and potential impact: the “Magic Pen.” This concept imagined a smart pen that travellers could carry to effortlessly capture memories and data on the go. The Magic Pen would serve as an intelligent travel diary companion: taking photos when pointed at a scene, recording audio or emotions. The pen would sync with a digital diary app, logging entries enriched by context (location, time) while prioritizing personal reflection over automatic metrics.



Figure 5. Brainstorming session during the “Travel Diary” workshop

## 5.2 Rapid Prototyping and Scenario Development

With the Magic Pen concept selected, the workshop moved into a rapid prototyping phase. Participants were given around 30 minutes to create a simple video prototype illustrating how the Magic Pen diary system might work, along with a short usage scenario (Figure 6 and 7).

Participants constructed a mock-up of the Magic Pen using a marker pen as a stand-in. They also used a regular notebook to simulate the digital diary, pasting printed photos and drawing simple lines to represent smart display features. Meanwhile, the story was based on a journey to Italy, where the pen is used to store travel details like tickets, maps, and plans. During the trip, the traveller removes information from the pen and transfers it to the notebook. The pen also offers feedback—such as warning if the trip is not eco-friendly. When the user swaps flight tickets for train tickets, the pen changes colour to reflect a lower carbon footprint. Throughout the journey, the pen captures sensory experiences: taking photos in a forest, recording sounds like birdsong during moments of discomfort (Figure 7). In one scene, the traveller shares their optimized, low-carbon itinerary with a fellow traveller simply by touching pens. Back at the hotel, all collected data—photos, moods, sounds, smells—is transferred to the notebook. After returning home, the traveller uses the pen to replay memorable music and sounds, triggering the notebook to display related visuals and experiences.



Figure 6. Storytelling in the “Magic Pen” video. Left: "I can copy the information from my trip into the pen"; centre: "and stick them in my physical notebook, the pen changes colour to indicate the environmental impact of my trip"; " I can share my experience and my diary by sharing my pen"



Figure 7. Mock-up scene of the Magic Pen capturing forest sounds during a low-carbon travel journey, where we used a large screen displaying a forest.

The prototype and scenario were presented to the group through a short dramatization. Participants role-played interactions with the pen, testing how intuitive it felt to use. This dramatization was recorded and edited into a video prototype, making the concept easier to preserve and analyse later. This phase exemplified how participatory prototyping allows users to shape and refine ideas by making them tangible and open to discussion.

### 5.3 Post-Workshop Systemic Analysis

After completing the workshop and producing the Magic Pen video prototype, the research team conducted a systemic analysis of the concept. This step aimed to identify potential indirect effects, feedback loops (Figure 8), and broader implications of widely adopting the Magic Pen. The analysis involved a follow-up session with selected participants and additional experts, applying two complementary systemic tools: Rebound Effect Archetypes (Bornes et al., 2024b) and causal loop diagrams.

Initially, the team applied the Rebound Archetypes framework (Figure 9) to systematically explore potential unintended consequences of Magic Pen adoption. For instance,

participants recognized that while the Magic Pen optimizes travel routes and enhances sustainability awareness, it might inadvertently encourage users to travel more frequently (B1: Bouncing Coin) due to cost savings or the perceived ease and enjoyment of sustainable travel. Additionally, intuitive feedback on carbon footprints provided by the Magic Pen could unintentionally lead to environmental complacency (B5: Lighter Soul), causing users to become less vigilant about other unsustainable activities. Furthermore, the accessible and appealing nature of Magic Pen might result in excessive recording and sharing of travel information, creating unnecessary data proliferation and increasing data storage demands (B3: Excessive Accessibility). Another critical risk discussed was the potential for greenwashing (B6), where companies might exaggerate the pen’s environmental benefits, misleading users and masking true ecological impacts. Participants also considered resource-related issues, such as increased demand for minerals needed for manufacturing, potentially leading to resource depletion and environmental harm (C7: Resource Depletion), and challenges with electronic waste management resulting from frequent upgrades or replacements (C10: Waste and Pollution). This detailed identification of rebound effects underscored the complex balance required when designing technologies intended for sustainability.

Next, the team developed causal loop diagrams to visualize systemic interactions clearly. Several important feedback loops emerged (Table 1).

Engagement Loop (R1)	Enhanced experiences from using the Magic Pen create stronger emotional attachments, leading to frequent upgrades and potential increases in electronic waste.
Sustainability Behaviour Loop (R2)	Frequent Magic Pen usage promotes shared sustainable routes and collective carbon awareness, encouraging widespread adoption of low-carbon travel.
Multimodal Transport Loop (R3)	The Magic Pen's support for multimodal travel can boost sustainable transport adoption and infrastructure investments, positively impacting long-term sustainability.
Rebound Effect Loop (B1)	Reduced travel costs from optimized routes might encourage users to travel more often, increasing demand for transportation resources and potentially offsetting initial sustainability gains.
Data Consumption Loop (B2)	Higher Magic Pen use increases demand for data storage, potentially raising energy consumption and carbon footprints unless mitigated by renewable energy solutions

Table 1. Analysis of indirect effects of the Magic Pen.



Participant profile and scale: The session involved a small, relatively homogeneous group (five members from the research team). Their shared background and experience might limit the generalisability to broader traveller populations.

Disciplinary scope: Sustainable mobility touches on economics, policy, and infrastructure, but no stakeholders from these domains were involved—limiting the systemic validity of identified leverage points.

Deployment: our analysis is pre-deployment, future work will track how workshop concepts are taken up and adapted in real settings (Ackerman, 2000).

These limitations inform the design of future case studies. Upcoming workshops will: (a) engage more diverse user groups, (b) include external experts in transport, ethics, and data governance, and (c) introduce iterative cycles where participants help build and refine systemic models. Subsequent studies will operationalise our stance through metrics: carbon budget per participant, evidence of modal shift, and the data/energy footprint of proposed features, with a check for rebound effect. In this way, the preliminary findings presented here become a foundation for deeper and more robust participatory-systemic inquiry in the next phases of the project.

## **6. Discussion and perspectives**

In this section, we build on the analysis and the dimensions we have identified so far to sketch out some perspectives.

### **6.1 Which participatory prototyping tools can be used for systemic analyses?**

This section explores how applying core participatory design principles, namely anchoring in the context of the user experience can facilitate the consideration of systemic issues in a participatory prototyping workshop for an interactive tool. The key question is therefore: which PD methods can support level- 2 interventions while being guided by level- 3 and level- 4 systemic analyses?

#### **6.1.1 Participatory prototyping**

Building prototypes with users is a core PD method: so, how could mock-ups foster systemic thinking while remaining rooted in the use of interactive tools? In the Magic Pen workshop, participants created storyboards and a mock pen, then acted out its use. This clarified the concept and fostered deep engagement. Responding to the “bouncing coin” rebound effect noticed after the workshop—that cheaper and greener route could tempt users to travel more—participants could be invited to generate ideas for a quick interface mock- up that would show, e.g. their cumulative kilometres, or other users' averages, or values that would be compatible with a carbon budget respecting planetary limits. More

subtly, this type of enactment would perhaps let participants step into a future where sustainable travels would be possible.

### **6.1.2 Speculative Design in Participatory Workshop**

Speculative design uses conceptual ideas to question current directions and open up discussion about possible futures. Design fictions, in particular, encourage people to imagine not just a product, but the world around it, which naturally brings systemic issues into view. The Magic Pen was a light example of this—it's not fully feasible yet, but imagining it helped question current travel-logging habits. If the workshop had been framed more explicitly as speculative, it might have led to bolder scenarios, like a world without flying or one overwhelmed by tourism. Speculative PD helps participants not just solve problems, but rethink assumptions and imagine new ways of living, which in turn would trigger systemic questions. Indeed, as Sanders and Stappers (2014) note, “designers and non-designers [can] work together, using making as a way to make sense of the future.”

### **6.1.3 Participatory Simulation Game**

Another promising avenue is participatory simulation games. Games can compress time and space, letting participants enact roles in a complex system over multiple “rounds.” There have been games (Chopra et al., 2022) for climate futures, urban planning, etc., where players see long-term outcomes of short-term decisions. Incorporating such a game in a PD workshop could effectively insert a systemic perspective in an intuitive way. For instance, a game could simulate 10 years of travel trends with and without the Magic Pen, so players (participants) directly observe rebound effects or societal changes, which then informs their design tweaks.

## **6.2 Systemic Design Tools in participatory prototyping workshops**

While the participatory activities produced a rich set of user-driven ideas and stories, Systemic Design (SD) tools were later used to place these outcomes in a broader context. In the case of the Magic Pen, two key techniques were applied: analysing potential rebound effects and creating causal loop diagrams (CLDs).

### **6.2.1 Anticipating rebound effects**

In the Magic Pen project, which presumably aims at some positive change (e.g., encouraging sustainable behaviour, improving learning outcomes, etc.), we explicitly introduced the concept of rebound effects during analysis (Figure 9) (Bornes et al., 2024). This systematic probing for side-effects was guided by the literature on systemic rebound phenomena. For example, imagine a European city whose narrow, winding streets prevent standard buses from entering the historic core. In a user-facing prototype, residents could

test a “last-kilometre” mobility service that combines mini electric shuttles with walk- navigation. By logging their chosen routes, waiting times and transfer counts, the tool would surface potential rebound effects—such as an uptick in discretionary trips or curb congestion triggered by the new shuttle’s convenience—so designers can iterate early on mitigating measures.

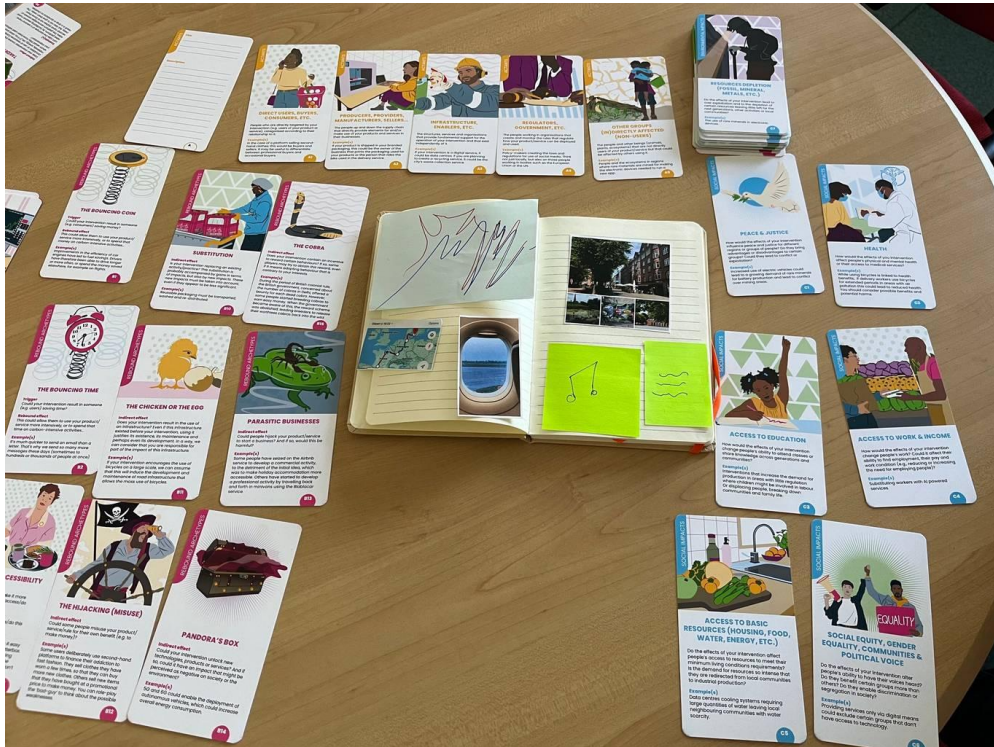


Figure 9. Rebound effect analysis using Rebound archetypes.

### 6.2.2 Causal Loop Diagrams

Causal Loop Diagrams (CLDs) are a core systems thinking tool that map variables and their cause-and-effect links as feedback loops. After the Magic Pen workshop, the team created a simple CLD to explore whether making travel logging easier might unintentionally encourage more travel and increase emissions.

Let's imagine that, with a view to designing the mobility service introduced in the previous section, we have interviewed citizens. In one of the interviews, a citizen reported an experience she had:

"In my town, two bus lines used to go through the city centre, where I live, and provided a direct connection to my workplace. Recently, however, the local council decided to remove or relocate several stops. The nearest one is now a 20-minute walk away. The bus route itself has also been extended, going from 20 to 30 minutes. As a result, it now takes me nearly an hour to get to work, whereas walking the entire way would take around 40 minutes. But since it rains often here,

walking isn't very practical, and the cycling routes are unsafe, so I'm too afraid to use a bike. Faced with this situation, I decided to get my driver's licence at the age of 50 and buy a car. Now, the drive to work takes only about 15 minutes."

An approach that we could experiment would be to collaboratively build a CLD of this situation with the person. The same quick sketch method can also explain local transport changes—for example, when two central bus stops were removed and the route was extended, a CLD revealed a reinforcing loop: fewer stops → longer travel time → buses less attractive → ridership drops → service gets cut → travel time increases. This helped explain why some residents switched to driving.

The Magic Pen workshop produced rich ideas focused on user experience, but systemic impacts like rebound effects only emerged later. This suggests participants need prompts to consider broader consequences. Simple tools and brief reflection questions could help surface these issues earlier in the process.

### **6.2.3 Envisioning futures methods**

The Three Horizons Map is a strategic foresight tool widely used in systemic design to help participants collaboratively explore transformation pathways from current conditions to desirable future states. This tool (figure 10) maps change pathways over time across three overlapping horizons: H1 (current regime and its decline), H2 (transition innovations), and H3 (desired longer-term future). In practice, groups place ideas or evidence onto a 3H canvas to contrast near-term fixes with structural shifts, then identify bridging moves from H2 to H3. Future State Scenarios (figure 11) complement 3H by selecting two key uncertainties to generate four contrasted futures and quick storyboards or enactments let participants experience design implications across futures (Jones & van Ael, 2022).

Applying the Three Horizons framework to the Magic Pen workshop could help participants explicitly connect their current travel habits and constraints (H1) with intermediate innovations such as multimodal transport facilitated by the Magic Pen (H2), ultimately mapping toward their ideal sustainable travel system (H3). A workshop organised around the Three Horizons could begin with participants making video sketches (Mackay, Ratzer, & Janecek, 2000) of several interactions for the Magic Pen. The group could then map these ideas onto a large 3H canvas, using personal experience to justify placement (e.g., "This solves a current issue—H1," or "This seems viable in a few years—H2") -- see an example on how to use an X-Curve (Hebink et al 2022) to structure brainstorming ideas in (Letondal et al 2023). A third step could be for the participants to continue video sketching to complement the three curves. Throughout the session, the emphasis is on linking systemic reflection to tangible design ideas. This also sets the stage for follow-up analysis, which can examine how ideas are distributed across the horizons and how

deeply participants engage with systemic thinking in later design rounds. Because PD participants are often unfamiliar with foresight tools, facilitators use simple prompts and sketching to keep the activity accessible while showing system-level assumptions.

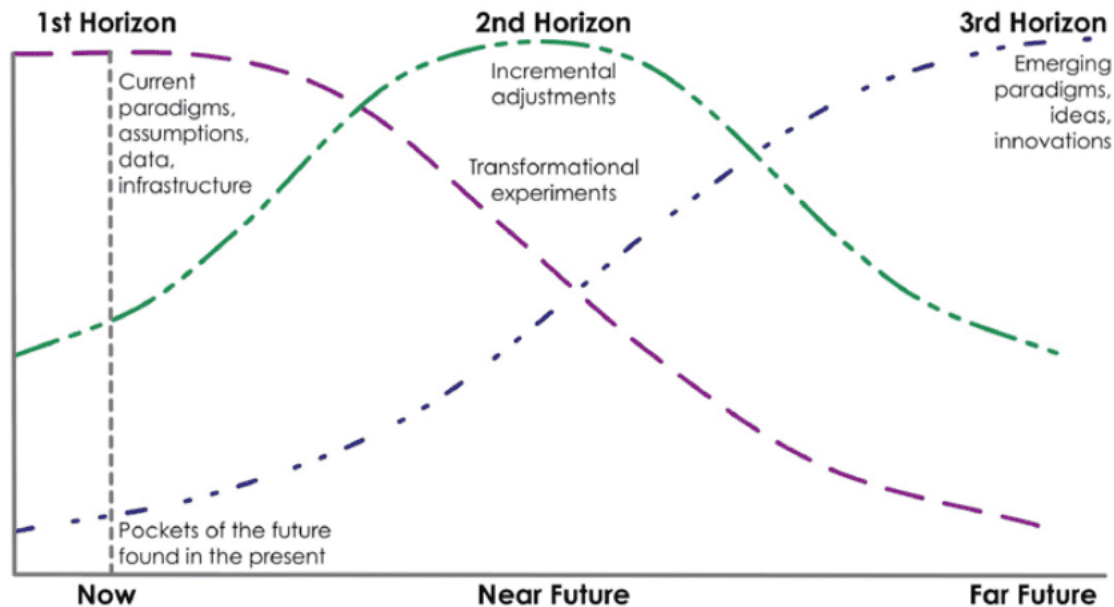


Figure 10. Three Horizons model. *Source: International Training Centre of the ILO (ITC-ILO)*

The Future State Scenarios method enables an object to be rethought by exploring several plausible futures with users. It is based on the identification of key uncertainties (technological, social, environmental, etc.) to build 3 to 4 contrasting scenarios. In the Magic Pen project, we could plunge users into one of these futures via scenarios and stories (Figure 6). These narrative methods, often called "embodied narratives" when drawn from lived experiences, can enrich systemic understanding by connecting individual stories to broader issues (Gao et al., 2025). A possibility would thus be to have participants imagine stories on how the magic pen would be used, perceived or transformed in different future states, using e.g. sustainability as a first variable and ease in mobility as a second variable. To make it easier for users to understand the four states of the future, and their emotional experience of them, we could consider using immersive techniques or projection techniques (Assor et al., 2024). By comparing the prototypes from each scenario, we could identify the essential elements, areas of risk and ethical choices that need to be anticipated. In this way, FSS provides a more systemic, critical and strategic approach to participative design, integrating uncertainty as a creative lever rather than a constraint.

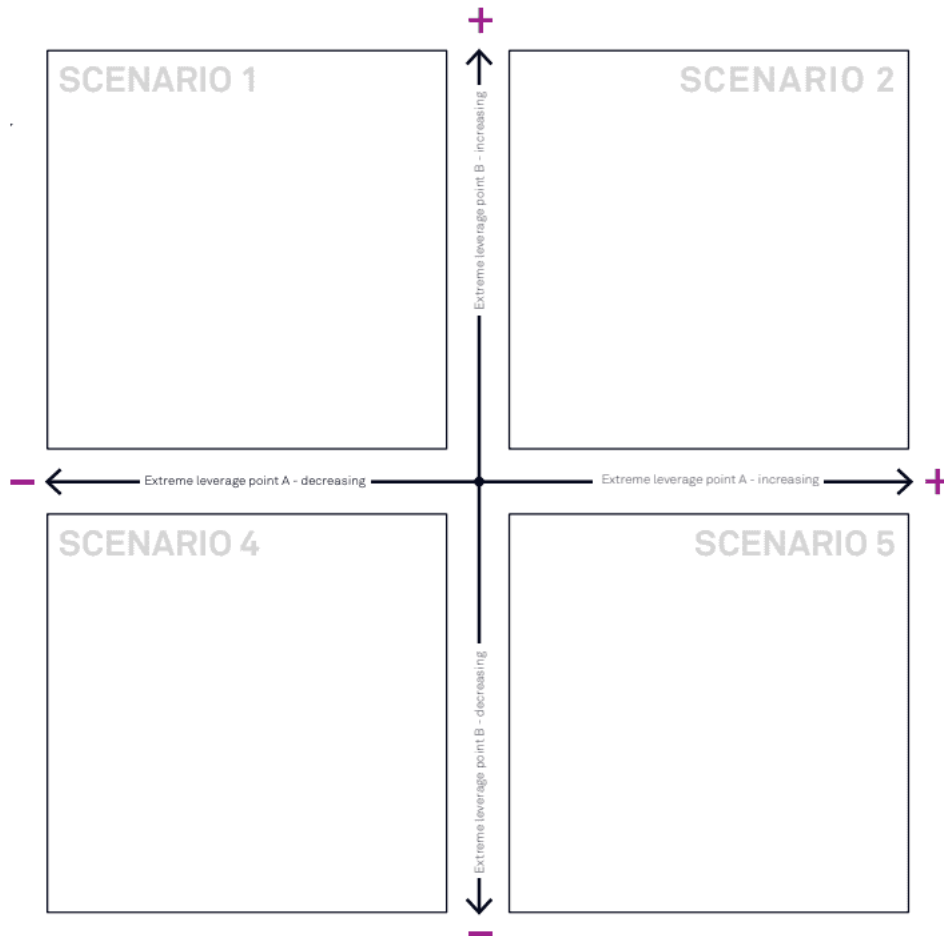


Figure 11. Future State Scenarios. Source : Van Ael et al.

Returning to our aim of linking Level-2 prototyping with Levels 3-4 reasoning, the Three Horizons and Future State Scenarios offer a gentle entry platform, widely presented as a simple way to start futures conversations with mixed audiences (International Futures Forum, n.d.; Jones & Van Ael, 2022).” Participants (most of whom will be unfamiliar with SD) first distribute examples across the 3H canvas, then compose scenario sketches. This keeps discussion accessible while opening Levels 3-4 questions; what emerges (leverage points, rebound concerns, longer-term commitments) immediately informs the sketches developed in the next prototyping round.

## 7 Conclusion

This paper outlines an initial approach for integrating systemic design into participatory prototyping methods. Based on a theoretical clarification of PD-SD asymmetry using analysis and intervention levels, the paper sketches the notion of systemic participatory prototyping. It highlights key methodological tensions and opportunities through an

exploratory case study. The “Magic Pen” workshop offered a concrete case that shows how this integration could work: low-fidelity prototyping, storytelling, and enactment keep users’ expertise in play, while systemic methods such as rebound-effect prompts and causal-loop diagrams can help participants spot unintended consequences early. As these prompts operate at design time, a full account of sustainability still requires following how concepts travel into practice. Methodologically, we propose a cross-level workflow in which levels 1-2 PD practices surface levels 3-4 insights through systemic prompts and facilitation.

In order to develop and iterate our methodology and tools, such as a facilitation toolkit (cards, canvases, guides), our next studies will explore them further based on our case study. We will convene multiple stakeholders including travellers, operators, planners, and advocacy groups in participatory systemic design workshops on multimodal transport. In these workshops, stakeholders will be invited to co-create low-fidelity prototypes and scenarios; facilitators will introduce simple systemic prompts (e.g., rebound archetype prompts, quick causal loop sketching, and Three Horizons mapping) so that Level-2 prototyping is explicitly connected to Levels 3-4 reasoning. Our objective is to consider a systemic issue involving actors at different levels. To this end, we have begun to study the design of digital tools and services in relation to a project for a single European multimodal transport ticket to combine e.g. air, rail, road, etc. To this end, we aim to hold Level-2 prototyping to strong sustainability limits by pairing hands-on making with systemic analyses.

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