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The Proof of the Pudding: Introducing quantitative testing in transition design reasoning

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Abstract

The urgent challenges of climate change, inequality, and declining societal well-being highlight the inadequacies of existing systems to meet sustainability goals. Transition design—a field at the intersection of design, sustainability science, and transition studies—has emerged as a response to these systemic issues. Despite growing interest in its practice, there remains a gap in understanding transition design processes, particularly regarding the effectiveness of resulting interventions in fostering systemic change. This study addresses this gap by proposing a conceptual framework that connects five essential transition design activities—navigating scales from micro to macro-level systems; considering temporality from the present to far future; engaging and repositioning actors from individuals and groups to networks; framing and designing from single solutions to portfolios; and practising reflexivity from activities to outcomes—to three evaluative qualities for its outcomes: desirability, plausibility, and networkedness of interventions. Using this framework, we assessed a portfolio of 21 proposed interventions that were designed to transition the Dutch food system to reduce food waste. Each intervention was presented as a drawing of a product-service system and was accompanied by a narrative of a user engaging with the intervention. The interventions were evaluated by consumers, companies, and experts through an embedded mixed-methods approach in which quantitative research was complemented by qualitative insights. Our findings reveal that while consumers and companies tend to favour near-future interventions that adapt existing food consumption practices, experts prefer long-term interventions that disrupt existing practices. Additionally, the results indicate that primarily quantitative evaluations may not sufficiently capture the complex, systemic qualities of transition design interventions, suggesting a need for a more balanced mixed-methods approach that incorporates context-sensitive insights. We conclude by reflecting on avenues for methodological development to improve evaluation as a (reflexive) transition design activity.

Keywords: Transition design, food waste, portfolio, design activities, evaluation, narratives, mixed-methods

1. Introduction

Today's societies are increasingly confronted with crises, like climate change, racial injustice, and socioeconomic inequality, that reveal systemic vulnerabilities and require transformative responses (Avelino et al., 2024; Geels et al., 2023). As these challenges are complex and interwoven, approaches integrating technical, political, and creative expertise are gaining attention as effective strategies for fostering desired societal changes (Gaziulusoy & Ryan, 2017a; Kossoff & Irwin, 2021). Transition design, a specialised field of design research and practice, offers an approach for facilitating and accelerating societal change towards more desirable alternatives through systemic interventions (Irwin, 2015). Situated at the intersection of design, sustainability science, and transition studies, transition design seeks to align short-term innovation efforts with long-term systemic changes (Goss et al., 2025d). Its potential to support deliberate societal transitions has stimulated growing interest in its processes and methodologies. However, there remains a gap in understanding and evaluating the outcomes of transition design, particularly in assessing the effectiveness of the resulting interventions. Therefore, the present study aims to answer the question: what is the perceived effectiveness of interventions resulting from a transition design process?

Once interventions for transitions have been designed, efforts to assess their impact within complex systems are inherently challenging, requiring approaches that reflect the dynamic and evolving nature of the context (Avelino et al., 2024; Sevaldson, 2022). As transition design is a relatively young field (Irwin, 2015), standard methods for its evaluation have yet to emerge, leaving it as an understudied area within the field. These considerations motivated us to develop a conceptual framework for transition design to 1) understand how transition design processes contribute to systemic changes and 2) provide qualities by which to evaluate its outcomes. The proposed framework connects five essential activities in transition design practice with three core qualities of transition design outcomes. In this study, we formulated hypotheses to support the evaluation of our framework by assessing a portfolio of 21 proposed interventions developed through a transition design process targeting food waste reduction in the Dutch food system. While we acknowledge that the effects of a transition design process cannot be assessed solely through its outcomes, examining these outcomes provides valuable insights into how such processes may contribute to systemic change. Through a mixed-methods approach, where quantitative research was complemented by qualitative insights, the 21 interventions were evaluated by three distinct actor groups—consumers, companies, and experts. Although we employed hypothesis testing, these hypotheses functioned not as traditional theory-testing tools but rather as structured evaluative criteria to guide and support our assessment.

This paper brings together both conceptual development and empirical application, providing a comprehensive contribution to transition design. Readers primarily interested in the conceptual foundations can focus on Sections 2-4, while those seeking empirical insights can find intervention development and evaluation in Sections 5-8. In the next section, we discuss how the concepts adopted in the framework are represented within the literature (Sections 2-4). This is followed by an overview of the transition design process that led to 21 proposed interventions (Section 5). We then present our hypotheses (Section 6), which are tested in a narrative-based study (Section 7), and present the results (Section 8). Finally, we conclude by reflecting on the practical and methodological implications for conceptualising transition design interventions and highlight areas for future research by which to strengthen transition design practice and evaluation (Section 9).

2. Transition Design Activities and Outcomes

2.1 Transition Design Activities

We focused on five essential activities for transition designers that emerged from the literature and from experiences from practice. These activities include: 1) navigating scales from micro to macro-level systems; 2) considering temporality from present to the far future; 3) engaging and repositioning actors from individuals and groups to networks; 4) framing and designing from single solutions to portfolios; and 5) practising reflexivity within and across activities and outcomes. These activities are reflected in our final framework (Figure 1).

2.1.1 Navigating Scales from Micro to Macro-level Systems

Transition design operates across multiple scales: the micro level, where individual behaviours, skills, and knowledge shape systemic change; the meso level, where organisations establish roles, relationships, and strategic directions for products and services; and the macro level, where policies, cultural values, and societal norms influence structural shifts (Geels, 2002; Rip & Kemp, 1998). Navigating these interconnected scales is fundamental, as change at one level can reinforce, constrain, or redirect shifts at another (Geels, 2002; Kossoff & Irwin, 2021; Overdiek et al., 2024; Rip & Kemp, 1998). For instance, organisational support at the meso level can amplify behavioural changes at the micro level, potentially influencing macro-level policies and cultural narratives (Fischer & Riechers, 2019; Smith et al., 2005).

To effectively interpret these cross-scale dynamics, transition designers have drawn on frameworks such as the Multi-Level Perspective (MLP) (Geels, 2002) and Social Practice Theory (SPT) (Reckwitz, 2002). The MLP explicitly conceptualises socio-technical transitions through interrelated levels: niches (where innovations emerge), regimes (dominant structures and practices), and landscapes (broad external forces like climate change or economic trends) (Geels, 2002). Meanwhile, SPT focuses on how everyday practices evolve through interactions between materials, skills, and meanings (Reckwitz, 2002; Shove et al., 2015). Together, these theories offer transition designers conceptual tools for understanding and strategically intervening across multiple scales, linking local actions to broader systemic transformations (Goss et al., 2025a; Irwin et al., 2022; van der Bijl-Brouwer et al., 2024).

However, designing across multiple scales presents challenges, particularly due to potential misalignments and resistance at different systemic scales and levels. Misalignments arise from differences in the speed, scope, or structural constraints inherent to each scale (Smith et al., 2005). For example, macro-level policy changes typically unfold slowly, often over decades, while micro-level behaviours may adapt more rapidly in response to targeted interventions. Resistance, on the other hand, emerges from political, economic, or social barriers that inhibit the implementation or acceptance of interventions (Smith et al., 2005). For instance, macro-level policy lock-ins or entrenched cultural values may hinder transformative shifts, meso-level organisational structures may find radical changes too disruptive, and individuals at the micro-level might resist interventions that significantly alter established practices (Geels, 2002). If these multi-scalar and level dynamics are overlooked, transition design interventions risk failing to achieve sustained systemic impacts. Therefore, transition designers must strategically position interventions, carefully balancing sensitivity towards existing structures with the ambition to drive systemic transformations.

2.1.2 Considering Temporality from Present to far Future

Transitions inherently unfold gradually, often spanning decades and requiring sustained, coordinated efforts to be planned across extended timeframes (Loorbach & Rotmans, 2010). Consequently, transition designers must adopt a long-term perspective, recognising that while future outcomes cannot be entirely predicted or controlled, present actions can shape evolving system dynamics (Irwin, 2018; Kossoff & Irwin, 2021; Murphy, 2022). Therefore, designing for transitions often begins with an understanding of both the envisioned future system and the current conditions in which designers wish to intervene. By understanding how current and future system dynamics interact, designers can develop interventions within existing structures that foster desired long-term transformations (Dorst, 2015; Goss et al., 2025a; Goss et al., 2025d).

To navigate these temporal dimensions, transition designers use methods such as visioning (e.g., Boehnert & Alexander, 2025; Goss et al., 2024), scenario development (e.g., Gaziulusoy & Ryan, 2017b), and pathway mapping (e.g., Hyysalo et al., 2019). These approaches enable designers to articulate clear transition pathways—also referred to as trajectories or directions— that guide interventions from present conditions towards envisioned futures. By adopting a long-term view, designers can overcome existing systemic constraints and imagine radically alternative practices that generate new meanings for individuals, organisations, and societies (Geels & Schot, 2007; Verganti & Öberg, 2013). This long-term orientation also situates new practices within evolving systemic contexts, helping designers anticipate obstacles, identify necessary resources, and establish milestones critical to the gradual introduction and adaptation of transition design processes.

Transition design inherently involves navigating tensions and trade-offs across varying temporalities. For example, the urgency to mitigate climate change may conflict with the slower processes needed to ensure equitable and just decision-making (Ciplet & Harrison, 2020). Similarly, intentional systemic changes, guided by stakeholder interests, governance structures, and organisational capacities, might move at different paces than broader systemic shifts such as technological developments, political instability, or climate crises. Transition efforts, therefore, exist within dynamic systems, requiring continual reassessment of risks, opportunities, and emerging conditions as circumstances evolve. Without recognition or sensitivity of these temporal complexities, transition design processes risk misaligning short-term interventions with long-term objectives, thereby undermining sustainable and just outcomes (Gibson, 2006).

2.1.3 Engaging and Repositioning Actors from Individuals and Groups to Networks

Transition design requires more than mobilising individual actors or isolated stakeholder groups to intentionally foster collaboration within and between actor networks (Kossoff & Irwin, 2021). These networks—coalitions of stakeholders operating at localised, sectoral, and cross-sectoral scales—collectively drive systemic change by leveraging diverse resources, knowledge, and influence (Löhr et al., 2022; Loorbach, 2007; Wittmayer et al., 2021). For example, in the context of food systems, actor networks may include organic farmers, local food distributors, community-supported agriculture initiatives, consumer groups, research institutions, and municipal policymakers. Understanding and effectively engaging with actor networks

enhances the coordination and coherence of interventions across different scales and sectors (Joore & Brezet, 2015; Wittmayer et al., 2017).

However, collaboration within actor networks is rarely smooth or linear. As transitions inherently challenge established systems, tensions and conflicts among stakeholders are inevitable (Geenen et al., 2022; Nedaei & Jacoby, 2023; Shaw & Solsø, 2024). Actors are often embedded in existing power relations, roles, and interests, which can lead to resistance when systemic shifts threaten their position. Additionally, transition processes may require actors to reposition themselves, adopt new roles, reshape services, or dissolve outdated organisational forms (Geels & Schot, 2007; Goss et al., 2025d). Recognising conflict as a source of systemic learning rather than as a barrier is critical for transition designers seeking to foster transformative change. Yet working with these tensions requires more than ad hoc participatory activities; it demands intentional efforts to sustain collaboration over time (Boztepe et al., 2024; de Koning & van der Bijl-Brouwer, 2024).

Sustaining active actor networks involves building resilient partnerships that support continuous knowledge-sharing, establishing governance structures that support joint decision-making, and designing adaptive processes that accommodate evolving stakeholder roles (Wittmayer et al., 2017). While many participatory design approaches, such as workshops or co-creation sessions (e.g., de Koning et al., 2018; Gaziulusoy & Ryan, 2017b; Goss et al., 2025d), successfully convene stakeholders to generate outcomes, their long-term effectiveness is limited unless there are structures in place to support ongoing collaboration. Thus, transition designers must move beyond short-term engagement strategies toward a more embedded, long-term presence within transition contexts. By proactively cultivating actor networks, facilitating role renegotiations, and safeguarding the values that underpin just transitions, designers can help foster adaptive, future-oriented coalitions capable of initiating and sustaining systemic transformations over time (Avelino et al., 2024; Goss et al., 2024; Hyysalo et al., 2019). This requires a commitment to remaining engaged across the unfolding phases of transitions, ensuring that efforts are not only initiated but also meaningfully embedded within the evolving dynamics of actor networks.

2.1.4 Framing and Designing from Single Solutions to Portfolios

While transitions aim to facilitate sustainable and just societies, the vast scope and complexity of related challenges call for a diverse range of interventions to foster desirable alternatives. Transition design recognises that systemic changes cannot be achieved by singular interventions; rather, it requires multiple interconnected solutions, each addressing aspects of a system while supporting broader transition dynamics (Gaziulusoy & Ryan, 2017a). Adopting a portfolio-based approach is, therefore, essential in transition design, as it enables designers to engage with systemic complexity from multiple perspectives and create varied entry points that collectively increase the resilience and efficacy of transition efforts.

A portfolio of interventions can span multiple system levels (e.g., household, community, city) and engage different domains of systemic activity (e.g., consumption, production, distribution). Portfolios can intentionally introduce new practices through new skills, meanings, and materials designed to evolve over different times in response to shifting contexts (Kossoff & Irwin, 2021; Kuijjer, 2014). Rather than pursuing a singular, definitive solution, transition design thus

embraces what Kossoff and Irwin (2021) call “solutioning over time.” This recognises that transitions unfold through continuous experimentation, adaptation, and recalibration. By fostering an iterative and evolving approach, portfolios aim not only to introduce alternatives but also to strategically disrupt entrenched structures and cultivate pathways toward more sustainable and just futures.

Crucially, portfolios can redistribute agency within transition processes. They create opportunities for a wide range of actors to participate as active drivers of change rather than passive recipients of predefined solutions (van den Bosch, 2010). By pursuing multiple interventions, transition design efforts become less vulnerable. For instance, if some interventions face challenges or fail to achieve desired changes, alternative interventions within the portfolio are still being explored and continue to sustain momentum. Furthermore, portfolios facilitate collective reflection among designers and stakeholders, enabling critical evaluation of the coherence, complementarity, strengths and gaps, and evolving relevance of transition efforts (Si et al., 2022; Whyte et al., 2022).

2.1.5 Practising Reflexivity, from Activities to Outcomes

Reflexivity is fundamental to transition design and is increasingly recognised as a critical skill for navigating complex systems change (Fitzpatrick et al., 2024; Vink & Koskela-Huotari, 2022). In this context, reflexivity is not simply an individual reflective practice but a deliberate process embedded in transition design processes. It requires designers to critically examine the assumptions, power structures, and decision-making processes that shape both the design process and its systemic outcomes (Fitzpatrick et al., 2024; Vink & Koskela-Huotari, 2022). Reflexivity ensures that design does not unintentionally reinforce problematic institutional logics or inequities but challenges entrenched structures to enable just transformation (Pel et al., 2023). In multi-stakeholder transitions, where diverse actors hold competing values, interests, and power positions, reflexivity helps designers navigate external pressures that may distort systemic intent. Rather than viewing transition design as a linear or purely technical process, reflexivity highlights its relational nature, where knowledge, values, and lived experiences continuously shape transition efforts (Bateson, 2017).

Additionally, embedding reflexivity into transition design processes enhances the adaptability and resilience of efforts, ensuring they remain responsive to shifting socio-political and environmental conditions (Fitzpatrick et al., 2024; Gibson, 2006). Although there is growing consensus on the importance of reflexivity, researchers continue to call for more practical tools—especially for supporting systems-level reflexivity—and for more empirical work to complement the field’s largely conceptual discourse (de Koning, 2019; Fitzpatrick et al., 2024; Lu & Sangiorgi, 2021; Vink & Koskela-Huotari, 2022).

2.2 Transition Design Outcomes

The preceding discussion highlights that transition design is an iterative process guided by five key activities that inform decisions about which interventions to propose, when to implement them, and how they should be combined. The outcomes of this ongoing process should reflect and embody these activities, producing a portfolio of interventions capable of driving systemic change. We specify that these outcomes as needed to demonstrate: 1) desirability across different actor groups

to enable uptake; 2) plausibility in fostering micro- (individual change), meso- (organisational change), and macro-level (systems change) transformations over time; and 3) networkedness, reflecting the interrelation of multiple interventions within a portfolio. This section discusses the literature on these three qualities (desirability, plausibility, networkedness) of transition design outcomes, which are also specified in the final framework (Figure 1).

2.2.1 Desirability

In transition design, desirability concerns the extent to which interventions align with the diverse needs, values, and expectations of different actor groups (e.g., citizens, organisations, and institutions). The literature discussed below highlights two key dimensions of desirability: 1) value, referring to the perceived benefits and relevance of an intervention for different actors, and 2) innovativeness, reflecting an intervention's novelty and capacity to inspire engagement and adoption. Together, these dimensions determine the extent to which an intervention aligns with the diverse interests of actors, thereby affecting its adoption and, ultimately, its potential impact.

Offering value to diverse actors

Understanding the perceived value of transition design interventions is crucial for their implementation, adoption, and sustained use (Ceschin & Gaziulusoy, 2016). Value is not an inherent property of an intervention; rather, it is context-dependent and shaped by actors' desires and anticipated outcomes (Harris, 2017). Because transition design interventions are embedded in everyday life, their perceived value depends on how well they align with the interests and expectations of diverse actor groups (de Koning, 2019; den Ouden, 2012). This embeddedness introduces complexity as different actors apply different evaluative criteria to interventions.

Consumers tend to prioritise personal relevance and experience, seeking interventions that improve daily life or offer emotional and symbolic meaning (Fokkinga et al., 2020). Companies, in contrast, assess interventions based on strategic fit, profitability, and competitive positioning, considering long-term business potential (den Ouden, 2012; Loorbach et al., 2010; Loorbach & Wijsman, 2013). Academic experts evaluate interventions based on their (systemic) impacts, conceptual robustness, and potential to shift problematic paradigms (Smith & Stirling, 2010). Meanwhile, the public sector emphasises societal impact, alignment with policy priorities (e.g., public welfare), and regulatory compatibility, often focusing on shorter-term benefits (Loorbach & Wijsman, 2013; Meadowcroft, 2009). Moreover, certain interventions, such as infrastructural projects or policy measures, operate at a systems level, where value is less connected to direct user experience and more concerned with structural change, regulatory stability, or long-term societal benefits.

These differing perspectives highlight a central challenge in transition design: interventions must align with the specific values of distinct actor groups while maintaining broader relevance to support collective innovation efforts. Without this cross-actor appeal, even technically robust and socially sound innovations will likely face resistance and limited adoption (Gaziulusoy & Ryan, 2017a, 2017b; Geels, 2002; Goss et al., 2024). Addressing this requires a values-based design approach that explicitly considers and negotiates diverse actor perspectives. For transition

designers, such an approach is critical not only for building initial momentum but also for sustaining engagement across the evolving dynamics of systemic change (Mok & Hyysalo, 2018; Ozkaramanli, 2021).

Providing innovative solutions

Innovativeness enhances desirability by introducing novel proposals that challenge conventional thinking and inspire new ways of acting (Irwin, 2015). Within transition design, innovativeness extends beyond simply developing new products or services; it entails reimagining system structures, behaviours, and social practices to support lasting systemic change. This process of reimagining is crucial, as innovative interventions must evoke curiosity, stimulate engagement, and offer a compelling sense of possibility to encourage their adoption and sustained impacts (Verganti, 2009). However, as with perceived value, perceptions of innovativeness vary across actor groups, creating complexity in how an intervention is assessed and prioritised.

For consumers, innovativeness is often associated with two dimensions of newness: form and function. Newness in form refers to aesthetic, symbolic, and experiential aspects, such as novel product designs, materials, and visual appeal. In contrast, newness in function relates to technological advancements, enhanced usability, and novel features that improve product performance and/or interaction (Lee et al., 2018; Mugge & Schoormans, 2012). Both aspects contribute to desirability by shaping how consumers perceive and engage with innovations in their daily lives. Academic experts typically assess innovativeness based on an intervention's ability to disrupt dominant paradigms and propose meaningful alternative practices (Irwin, 2018; Tromp & Hekkert, 2018). For these actors, innovative interventions provoke reflection, open up new imaginaries, and shift perspectives towards systemic changes (Dunne & Raby, 2013; Irwin, 2018; Tromp & Hekkert, 2018). Alternatively, companies typically prioritise innovativeness in terms of market differentiation, scalability, and competitive advantage, focusing on how new ideas can translate into profitable business models (den Ouden, 2012; Teece, 2010). Finally, the public sector tends to favour incremental innovation that aligns with policy priorities and cycles, as well as existing infrastructures, seeking solutions that can be integrated without major disruptions while still offering long-term benefits (Meadowcroft, 2009).

Beyond these differences, innovativeness in transition design must also be understood as unfolding across different time horizons. Innovations focused on the present tend to be incremental, improving current systems within existing constraints and thus resulting in minimal disruption (Norman & Verganti, 2014). In contrast, near and far-future innovations introduce greater novelty and speculative possibilities, potentially repositioning actors toward long-term transition aims (Dunne & Raby, 2013; Geels, 2002; Goss et al., 2025d). Far-future interventions, in particular, are often the most inspirational, as they challenge existing paradigms and envision new cultural traditions, social practices, and institutional structures (Tromp & Hekkert, 2018; Verganti & Öberg, 2013). However, realising such transformations requires time for regulatory adaptation, infrastructural shifts, and societal acceptance (Irwin, 2015; Vezzoli et al., 2015). By supporting actors to imagine compelling alternative futures, transition design interventions not only introduce novelty but also inspire shifts in mindsets and behaviours, enhancing the desirability of long-term transition processes.

2.2.2 Plausibility

In transition design, plausibility concerns the perceived achievability of the impact of interventions within current and envisioned societal systems. The literature discussed below highlights two key dimensions of plausibility: 1) an intervention's capacity to foster behavioural changes and 2) its contribution to addressing societal challenges along a transition pathway. As such, transition designers must evaluate interventions based on the intervention-level attributes (e.g., aims, behavioural mechanisms, form, function), their alignment with transition pathways, and the likelihood of achieving intended systemic shifts (Wiek et al., 2013). This ensures that interventions are not merely visionary but are “occurable” (Wiek et al., 2013), meaning they can realistically trigger behavioural changes within the systemic context where they are implemented (Ceschin & Gaziulusoy, 2016).

Fostering desired behavioural changes

Addressing behavioural changes is paramount for transition design interventions, given that transitions fundamentally alter established patterns of consumption and production to more sustainable alternatives (Gaziulusoy & Brezet, 2015; Scott et al., 2012). As such, transition design interventions that overlook behavioural dimensions risk being ineffective, as technological or policy changes alone cannot guarantee the adoption of sustainable practices (Shove, 2010). To drive transformative changes, interventions must consider the underlying values, habits, and social norms that shape individual and collective behaviour (Jackson, 2005). By focusing on intended behavioural changes, interventions can facilitate the development of new routines and lifestyles and create the social conditions necessary for sustainable and equitable futures (Geels, 2011; Kuijer, 2014).

Designing for behaviour change requires sensitivity to contextual factors, such as cultural norms, economic conditions, and local infrastructures, which shape how behaviours emerge, adapt, and become embedded over time (Mok & Hyysalo, 2018; Verbeek, 2005). These contextual aspects act as the “materials” of design, influencing the adoption and maintenance of new behaviours (Vink & Koskela-Huotari, 2022). While individual behaviour change is well-studied in design (Maier & Cash, 2020), insight into systemic behaviour change is still developing (van der Bijl-Brouwer et al., 2024). To be effective, interventions must address both individual and systemic changes simultaneously, as focusing on only one aspect, such as only individual change without supporting systemic changes, or vice versa, is unlikely to drive societal transitions (Goss et al., 2025a).

Contributing to societal challenge along a pathway

For transition design interventions to be effective, they must directly address a clearly defined societal challenge (Loorbach, 2007). Since transitions fundamentally seek to shift complex societal systems in response to persistent challenges like climate change, inequality, or resource depletion (Geels, 2011), interventions disconnected from these challenges risk being perceived as superficial or peripheral, undermining their potential to drive lasting changes (Gaziulusoy & Brezet, 2015; Irwin, 2018; Rotmans et al., 2001). Grounding interventions in a clearly articulated societal issue strengthens their ability to mobilise stakeholders, leverage existing momentum, and create a shared sense of urgency and collective action and needed for transformation (Loorbach, 2007; Meadowcroft, 2009).

Beyond issue identification, aligning interventions with strategic transition pathways is crucial for achieving the desired transformation because pathways provide a frame for navigating intended societal shifts (Rotmans et al., 2001). For instance, pathways articulate the desired trajectory of change and anticipate key milestones and obstacles, enabling interventions to be strategically aligned and targeted in ways that contribute to broader transition goals through a coherent and coordinated approach (Geels, 2011; Goss et al., 2025a; Hyysalo et al., 2019; Smith et al., 2005). Interventions that lack alignment risk becoming fragmented efforts, limiting their capacity to contribute meaningfully to broader transition goals. Therefore, aligning with a recognised societal issue along a pathway enhances the legitimacy and relevance of interventions, increasing stakeholder buy-in and facilitating long-term desired changes (Loorbach, 2007; Meadowcroft, 2009).

2.2.3 Networkedness

A portfolio is a collection of networked interventions designed to address multiple dimensions of a complex societal challenge. A diverse portfolio, with interventions of varying types and degrees of disruption, increases the chances of engaging a variety of actors at different system levels, improving adoption and implementation (Klingebiel & Rammer, 2014; Si et al., 2022). It ensures that even if some interventions encounter obstacles, the overall system remains capable of progressing towards desired outcomes (Klingebiel & Rammer, 2014; Si et al., 2022). Additionally, a diverse portfolio of interventions enables actors to contribute to immediate improvements while also laying the groundwork for transformative changes, balancing incremental and radical interventions (Loorbach et al., 2010).

Transition design portfolios must also be complementary, synergistic, reinforcing, and coherent. Complementarity ensures that interventions target different actors, behaviours, and system levels, collectively addressing various aspects of the challenge (Geels & Schot, 2007; Markard et al., 2012). For instance, one intervention might focus on encouraging consumers to use leftovers more effectively, while another targets legislation to improve food labelling practices to reduce confusion regarding expiry dates. Synergy emerges when interventions interact to amplify their combined impacts (Irwin, 2015; van den Bosch, 2010). Continuing the same example, educating consumers on leftover use alongside clearer expiration date labels would likely have a greater effect together than either intervention would have alone. Reinforcement strengthens this further, ensuring that one intervention supports the success of another (Smith & Stirling, 2010). For instance, if government policies promote food labelling while simultaneously incentivising businesses to adopt waste-reducing packaging, these interventions reinforce each other, creating a more cumulative shift. Finally, coherence in the portfolio ensures that interventions work within a unified strategic vision, whereby each intervention addresses a different aspect of the challenge—e.g., from consumer practices to business models to legislation (Dorst, 2011; Nguyen et al., 2018).

2.3 Transition Design Framework

We introduce a conceptual framework (Figure 1), linking five essential activities of transition design in the outer ring with three evaluative qualities of its outcomes in the inner ring. Building on the literature reviewed, we argue that these five activities—navigating scales, considering temporality, engaging and repositioning actor networks, framing and designing portfolios, and practising reflexivity—are essential

for conceptualising and practising transition design in response to complex societal challenges. These activities, rather than being linear steps, are integrated throughout the transition design process, influencing decisions and shaping interventions to address systemic complexity. Ultimately, they contribute to the design of interventions that are desirable for various actors in the transition, plausible for transforming behaviour over time in response to a societal issue, and, in combination within a networked portfolio, reflect a strategy for systems change



Figure 1. Framework representing five key transition design activities, connected to 3 key evaluative qualities of transition design interventions.

3. The FETE Transition Design Process

This section presents the transition design process used to develop proposed interventions, showing how the five activities were integrated across different design phases. Each intervention was then conceptualised as a drawing of a product-service system and accompanied by a narrative of a user engaging with the intervention. To evaluate the interventions, we developed hypotheses based on the three qualities—desirability, plausibility, and networkedness—and employed survey questions to gather insights from consumers, companies, and experts through a mixed-methods approach.

3.1 Project Setting

The Netherlands, a leading producer and exporter of agricultural products, significantly shapes global food systems (Berkhout et al., 2018). Despite its influential

role, the Dutch food system faces challenges similar to those of other developed nations, notably driven by societal expectations of abundance, convenience, and continuous availability (Evans, 2011, 2014). While prioritising excess and variety may satisfy consumer demands, it leads to considerable societal costs due to inefficient resource use (FAO, 2020). A major consequence of this is food waste, defined as unnecessarily discarded food that could have been used for human consumption (van Dooren & Knüppe, 2020).

Approximately one-third of food produced globally is wasted annually (UNEP, 2024). This level of waste strains resources, exacerbates food insecurity, and results in considerable economic and environmental costs (UNEP, 2024). Notably, food waste generates unnecessary greenhouse gas emissions from food production, distribution, and disposal, further intensifying pressure on ecosystems. As such, reducing food waste is widely recognised as one of the most effective strategies for addressing climate change (Bajželj et al., 2020; Beddington et al., 2012; Drawdown, n.d.; Stuart, 2009). In affluent countries like the Netherlands, food waste predominantly takes place at the consumer and retail levels (Beddington et al., 2012). For instance, in 2020, in the Netherlands, consumers generated the largest share of food waste, approximately 161 kilograms per capita, accounting for 36% of total national food waste (Soethoudt & Vollebregt, 2023). With the Netherlands' intention to halve food waste by 2030, in accordance with Sustainable Development Goal (target) 12.3, the country faces critical challenges in achieving this goal due to entrenched consumption and production practices (Lieshout & Knüppe, 2022).

This research is part of the From Excess to Enough (FETE) project, a collaborative initiative established in 2020 in response to the urgent challenge of reducing food waste in the Netherlands. FETE brings together three Dutch universities and eight commercial and non-profit food system partners. The industry partners represent various roles and perspectives within the food system and include a national nutrition centre, a food waste foundation, an IT consultancy, a frozen food manufacturer, a waste collector, a food-focused business school, and a meal delivery service company. Together, the consortium explores how innovative consumer and retail practices, supported by novel business models, can facilitate a transition towards a food system based on 'enough' rather than excess.

The transition design process followed in this research was iterative, moving between pragmatism and theory— which is typical of transdisciplinary research—while navigating the activities outlined in our framework to ensure interventions met the identified qualities (Figure 1). Throughout the design process, actors across multiple levels of the food system, both within and outside of the FETE consortium, were actively engaged. Given that the FETE partners focused on the household context rather than agricultural production, the design process focused on conceptualising micro-level interventions while linking these to meso- and macro-level systemic changes. For instance, enhancing food literacy through new product labels implies changes to organisational communication and wider packaging legislation. Moreover, the design process explored how interventions evolve temporally, aligning short-term adaptations with a long-term food system transition. The resulting portfolio consists of seven intervention sets, each with three variations, amounting to a total of 21 proposed interventions. All the interventions were designed to foster flexible and adaptable food consumption behaviours to reduce waste (Figure 5).

The transition design process toward these interventions followed five phases:

1. Developing a vision of a future food system
2. Aligning actor innovation efforts around a new food consumption practice (i.e., Adaptable consumption)
3. Exploring how to embed this practice within daily life through an intervention portfolio
4. Iterating on the proposed interventions to strengthen their transition design reasoning
5. Evaluating the effectiveness of the intervention portfolio in fostering systemic change

An overview of the process is shown in Figure 2 and briefly described below. The present study focuses on the final phase: evaluating the proposed portfolio to assess its systemic potential and reflect on the transition design process. While outcomes cannot fully capture the effects of a transition design process, they offer valuable insights into its contribution to systemic change.

	 1. Developing a shared vision	 2. Aligning toward a transition pathway	 3. Embedding change in everyday life	 4. Refining transition design reasoning	 5. Evaluating intervention proposals
Approach	Participatory visioning led by design agency that engaged 18 food system actors and experts in interviews, as well as FETE partners in 5 co-creation sessions.	2 innovation workshops together with FETE industry partners.	Diary and interview study that engaged 11 Dutch households.	Design sessions that synthesised feedback from food system partners and consumers to iterate upon the interventions.	Narrative-based evaluation with 312 consumer, company, and expert participants.
Process outcome	Vision of a future food system that provides enough food for all with minimal waste based on systems principles.	New consumption practice for the pathways of Embracing Flexibility. The pathway is supported by a proposed intervention portfolio.	Insights on embedding adaptable consumption and its proposed interventions in everyday life.	Visual overview of feedback from phase 2 and 3, and an updated portfolio with explicit transition design reasoning.	Insights into the effectiveness of the proposed interventions in fostering the transition from excess to enough along the path of embracing flexibility.
Design outcome	Animated video and vision report.	User scenario and innovation portfolio.	5 opportunities for supporting household in adopting adaptable consumption.	Updated visualisations of 21 proposed interventions along with 21 narratives communicating each intervention.	
Activity practised	<ul style="list-style-type: none"> 🌀 <i>Navigating scales</i>: aligning micro-meso-macro changes. 🕒 <i>Considering temporality</i>: projecting future changes. 👥 <i>Engaging actors</i>: co-developing a desired future vision. 📐 <i>Framing & designing</i>: translating possible systems into tangible principles. 	<ul style="list-style-type: none"> 👥 <i>Engaging actors</i>: co-developing shared strategies and pathways to 'enough'. 🕒 <i>Considering temporality</i>: extrapolating behavioural changes over time. 📐 <i>Framing & designing</i>: designing interventions within a portfolio. 	<ul style="list-style-type: none"> 👥 <i>Engaging actors</i>: engaging consumers as experts of their own experiences. 📐 <i>Framing & designing</i>: integrating interventions into lived experiences. 	<ul style="list-style-type: none"> 🌀 <i>Practising reflexivity</i>: evaluating and adjusting portfolio assumptions. 📐 <i>Framing & designing</i>: explicating transition design reasoning for interventions. 🌀 <i>Navigating scales</i>: aligning interventions across micro-meso-macro levels. 🕒 <i>Considering temporality</i>: explicating anticipated influence of interventions over time. 	<ul style="list-style-type: none"> 🌀 <i>Practising reflexivity</i>: assessing design process and outcomes. 🌀 <i>Navigating scales</i>: evaluating systemic relevance. 🕒 <i>Considering temporality</i>: assessing influence of interventions over time. 👥 <i>Engaging actors</i>: assessing interventions with three key actors groups.
Intervention quality	<ul style="list-style-type: none"> 🔗 <i>Desirability</i>: aligning long-term aspirations with actors' values. 🔗 <i>Plausibility</i>: grounding vision in realistic future developments. 🔗 <i>Networkedness</i>: engaging diverse system actors in co-creating solutions. 	<ul style="list-style-type: none"> 🔗 <i>Desirability</i>: ensuring alignment between future vision and actor priorities. 🔗 <i>Plausibility</i>: mapping routes for change. 🔗 <i>Networkedness</i>: developing a portfolio of joint interventions. 	<ul style="list-style-type: none"> 🔗 <i>Desirability</i>: ensuring interventions resonate with consumers. 🔗 <i>Plausibility</i>: embedding interventions within daily practices. 	<ul style="list-style-type: none"> 🔗 <i>Desirability</i>: refining interventions based on multi-actor input. 🔗 <i>Plausibility</i>: evaluating path of change for each intervention. 🔗 <i>Networkedness</i>: enhancing coherence across interventions in the portfolio. 	<ul style="list-style-type: none"> 🔗 Reporting findings on <i>desirability, plausibility, and networkedness</i> of proposed interventions.

Figure 2. Overview of the transition design process, activities, and outcomes undertaken and its connection to the conceptual framework.

3.2 Design Phases

The first phase established a shared vision of a future food system in the Netherlands through a participatory process led by a design agency (Figure 3). This phase engaged actors from within and beyond FETE to co-create a desirable future scenario for 2030 focusing on “future food practices.” The designers used the Vision in Design method (Hekkert and van Dijk (2011)) to support them in developing proposals grounded in the intended societal and behavioural impacts they aimed to facilitate in the future. The designers conceptualised this effect in reference to an anticipated future context, including both positive and negative developments. This helped them to avoid fixation on problems in the current food context and to work with the opportunities the future brings. While the description of the future food context was as neutral as possible—reflecting plausible and possible futures—the innovations as a response to the future were deliberately normative, transforming toward preferable futures. The resulting vision emphasised a future food system that prioritises vitality, embraces flexibility, celebrates the food journey, and leverages technology for learning. By linking individual food behaviours (micro) to organisational practices (meso) and societal norm changes (macro), and by considering how food practices might evolve over time, this phase laid the foundation for identifying systemic opportunities and barriers that informed subsequent phases (see Goss et al., 2024).

Building on this shared vision, the second phase introduced Adaptable Consumption—a proposed practice enabling households to adjust their food provisioning to minimise waste (Goss et al., 2025b; Goss et al., 2023, 2025d). The practice integrates flexibility (e.g., ingredient substitution, meal plan adjustments) and adaptability (e.g., using suboptimal food, optimising storage) to facilitate waste-free and flexible behaviours in daily life while contributing to broader systemic changes. Adaptable consumption was developed through two workshops with FETE food system partners, who identified Embracing Flexibility as a key strategic pathway for reducing food waste. They highlighted that existing Dutch food safety regulations highly prioritise safety over sustainability, limiting opportunities to experiment with new innovations. Discussions emphasised the need to realign values, balancing safety, quality, and sustainability (see Goss et al., 2023, 2025b).

To translate adaptable consumption into tangible design directions, we developed a user scenario depicting a family engaging in the proposed practice and an innovation portfolio with seven intervention concepts, each presented in three variations (Figure 4). The user scenario illustrated six key behaviours for the new practice: mixing and matching ingredients and flavours, assessing food quality with the senses, adjusting recipes for different portions, thinking on a meal level, adjusting food purchasing based on how much food they waste, and storing leftovers effectively to integrate them into meals. By framing adaptable consumption as an evolving practice, this phase developed intervention sets that also reflected a behavioural evolution over time. The proposed interventions emerged through an iterative designerly process, balancing conceptual exploration with practical considerations for what might evolve in the present, near future, and far future, and how flexible and waste-reducing behaviours might be supported at home (see Goss et al., 2023, 2025b).

The third phase examined how adaptable consumption could integrate into consumers’ daily routines in ways that reflected their lived experiences. Through diaries and interviews with 11 Dutch households, we identified five key opportunities for adaptable consumption in homes: supporting flexible meal moments, reclaiming the edibility of food, reintegrating food into routines, integrating feedback loops,

and playing into life-changing moments. These highlight how behavioural, material, and social dimensions shape food consumption, revealing ways to reduce waste and enhance household flexibility. For instance, flexible meal moments allow households to break from rigid routines and encourage the creative use of ingredients, while reclaiming food edibility through evaluating sensory cues or obtaining second opinions can prevent premature food disposal (see Goss et al., 2025b).

The fourth phase focused on refining the intervention portfolio based on insights from both the FETE actors (phase 2) and consumers (phase 3). Through a structured synthesis of feedback, each of the 21 interventions was iteratively refined to support intended behavioural impacts on flexibility and waste reduction, thereby contributing to adaptable consumption. For instance, one design rationale for a new food waste bin is as follows: by offering consumers insight into how much and what food they waste, they will have better visibility into their waste situation and be better equipped to adjust what they buy based on what they waste (individual behaviour). This feedback increases their confidence in food provisioning for ‘enough’ and helps them feel more empowered to adapt their consumption practices (individual value). By introducing information flows about food waste on the household level, more targeted behavioural change can be introduced to reduce food waste (system behaviour). This information can be used to optimise food packaging, separation techniques, and communication around food waste and to support various system policies and initiatives (e.g., province, municipality, neighbourhood) (systemic value). In this phase, we also revisited how interventions functioned as a portfolio, ensuring they targeted distinct yet complementary behaviours.

The final phase of the process, reported in this paper, focused on evaluating the proposed interventions to assess their desirability, plausibility, and networkedness as outlined in our framework (Figure 1). This large-scale study, conducted with consumers, food system companies, and experts, provides insights into the perceived effectiveness of the proposed interventions and their potential to contribute to a transition toward a food system with minimal waste.



Figure 3. Impression of the form-giving of the video and report presenting a future vision for 2030. Video by Freek Trimbach. Drawings and report by Reframing Studio.

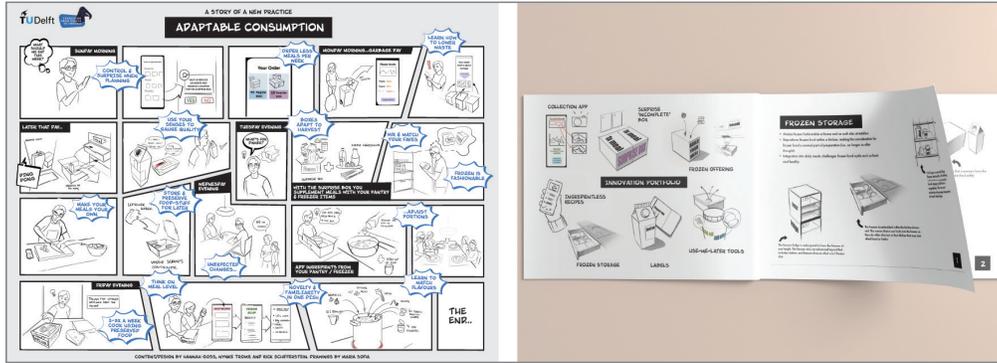


Figure 4. Comic strip for Adaptable Consumption and proposed interventions, with three variants for different timeframes. Drawings by Maria Sofia.

Set	Time variation 1 (present)	Time variation 2 (near-future)	Time variation 3 (far-future)
Waste Bin Insights	PSS 1 Countertop waste bin Indicates the number of wasted food portions.	PSS 2 Smart food waste bin Tracks food waste levels and types, providing data and tips for consumption practices.	PSS 3 Smart kitchen system Uses a grocery app to optimise shopping based on food consumption, stock, and waste patterns.
Use-me-later Tools	PSS 4 Preservation duo Containers that extend ingredient shelf-life and provide preservation tips.	PSS 5 Food life-extending tools Includes dehydrators, freezers, and vacuum storage for optimal preservation.	PSS 6 Preservation pods Equipped with sensors to monitor and maintain food freshness.
Freezer Integration	PSS 7 Fridge-freezer drawers Keeps food organised, visible, and in optimal condition.	PSS 8 Quick-freeze and defrost device Maintains ingredient quality and simplifies meal preparation.	PSS 9 Speed freeze bags Improves frozen ingredient visibility, nutrient preservation, and enables quick defrosting.
Frozen Ingredients	PSS 10 Frozen meal packages Tailored to dietary needs for better meal integration.	PSS 11 Personalised frozen meals Optimises portion sizes and ingredient selection.	PSS 12 Dissolvable packaging Enhances visibility, preservation, and portioning of frozen ingredients.
Consumption Boxes	PSS 13 Consumption boxes Mix of fresh and long-shelf-life ingredients to simplify meal preparation.	PSS 14 Integrated boxes Syncs with household schedules to adjust meal plans and preferences.	PSS 15 Growth boxes Adapts ingredients and portions based on evolving needs.
Assessment Labels	PSS 16 Freshness labels Helps determine ingredient freshness and safety.	PSS 17 Sensory labels Guides food evaluation through smell, texture, and other sensory inputs.	PSS 18 Minimalist labels Displays production date for consumers to assess food quality using existing food knowledge.
Ingredientless Recipes	PSS 19 Ingredientless recipes Encourages improvisation with available, local, and seasonal ingredients.	PSS 20 Ingredientless menus Supports meal planning around seasonal, local menus instead of specific ingredients.	PSS 21 Ingredientless eating Promotes cooking based on techniques, styles, and flavors rather than fixed ingredients.

Figure 5. Overview of the 21 product-service systems designed and tested in this study, showing the intervention set they belong to. Drawings by Sterre Witlox.

4. Hypotheses

Based on our conceptual framework, we formulated a series of hypotheses to examine the perceived desirability, plausibility, and networkedness of the proposed interventions. By investigating these qualities, we aim to determine the potential effectiveness of the interventions in fostering desired systemic change, i.e. supporting adaptable consumption as a strategy to reduce food waste. The hypotheses (detailed below) address three hierarchical levels: the portfolio, the intervention sets, and the individual product-service systems (proposed interventions). Rather than serving as traditional theory-testing tools, these hypotheses function as structured evaluative instruments, enabling us to assess both the characteristics of the interventions and, indirectly, the effectiveness of the transition design process that created them.

4.1 Desirability

Given that the transition design process engaged diverse actors and that the interventions were designed to support a new practice of consumption that aligns across timeframes, we hypothesise that:

H1—There is a positive perceived desirability reported across all groups

H2— The perceived innovativeness increases with time (Time 1 < Time 2 < Time 3)

H3—The time to market increases from Time 1 to Time 3 (Time 1 < Time 2 < Time 3)

4.2 Plausibility

Given that the interventions were designed along a pathway toward the transition in a multiple-actor setting, we hypothesise that:

H4—There is a positive perceived plausibility reported across all groups

H4 is tested using:

H4a—There is a positive perceived likelihood to contribute positively to the systemic pathway (i.e., minimise food waste and support flexibility)

H4b—There is a positive perceived likelihood to lead to the intended behavioural effects

H5—Far away interventions are equally plausible to near interventions, as the design process was created for that (Time 3 = Time 2 = Time 1)

H6—The effects of the interventions on food waste reduction are mediated by increasing flexibility (i.e., the interventions contribute to the societal challenge of food waste through the pathway of embracing flexibility)

4.3 Networkedness

Given that a portfolio of interventions was designed to support an envisioned practice, we hypothesise that:

H7a—There is perceived diversity among intervention sets within the portfolio

H7b—There is perceived complementarity between the intervention sets

H7c—There is perceived synergy among the intervention sets

H7d—There is perceived reinforcement among the intervention sets

H7e—There is perceived coherence among the intervention sets

5. Method

This study employed an embedded mixed-methods design, in which a primarily quantitative research survey approach was complemented by qualitative insights from open-ended survey responses (Almeida, 2018). In this type of design, both forms of data are collected and analysed concurrently, but the qualitative component plays a secondary, supportive role within the broader quantitative framework. We used this approach to examine how different actor groups evaluated 21 proposed interventions aimed at supporting systemic changes in the food system. The evaluation was informed by a literature review that shaped the conceptual framework, which we subsequently tested through narrative-based interventions and a structured, multi-factorial design. To gather these evaluations, participants assessed each intervention using a questionnaire that combined structured response scales with open-ended questions. Each intervention was introduced through an illustrated drawing accompanied by a narrative describing how a person would interact with the intervention in everyday life.

Narratives, widely used in design, were chosen for this study given their effectiveness in allowing individuals to imagine hypothetical situations and assess the behavioural impacts of prospective products (Tromp & Hekkert, 2016; van der Maden, 2024). They have been recognised as effective tools for evaluating speculative interventions, particularly when aiming to understand behavioural implications in imagined or speculative contexts (Candy & Dunagan, 2017; van den Hende, 2010). Rather than evaluating real-world effectiveness, narratives enable participants to assess whether interventions are desirable for various actors in a transition, whether they are plausible for transforming behaviour over time in response to a societal issue and pathway, and—when considered as part of a networked portfolio—reflect a strategy for systems change. A crucial aspect of narrative studies is the believability of the narratives themselves, as deeper engagement in stories enhances participants' ability to provide realistic evaluations (Green & Brock, 2000; Shapiro et al., 2010). While this narrative approach enables rich, future-oriented engagement with systemic change concepts, we acknowledge that participants' evaluations are interpretive and based on imagined scenarios rather than real-world trials.

The study involved three distinct participant groups: consumers, companies, and experts (e.g., designers, food scientists, and behavioural change researchers). These groups were selected to reflect the need for transition design interventions to align with individual behaviours and organisational contexts to foster desired changes. Participants evaluated seven product-service systems (PSS), one from each of the seven sets (see Figure 5). The PSS variation and the order in which they were presented were randomised. This setup allowed us to mitigate order effects, avoid a systematic difference in the distribution of participants across the three time variations between the seven sets, and minimise participant fatigue by limiting the amount of information being processed.

The study was conducted between July and October 2024, and it obtained ethics approval (approval number 1332) from the university's Human Research Ethics Committee.

5.1 Participants

The study included three distinct participant groups—consumers, companies, and experts—selected to provide diverse perspectives on the research topics. Appendix A provides an overview of the demographic and background characteristics of these groups. Due to time and resource constraints, the study was conducted in English, and all participants were fluent in the language. Care was taken to avoid overly complex wording in the study materials, and Dutch translations were provided for less familiar terms where necessary. Additionally, participants could respond to open-ended questions in Dutch, which were later translated for analysis.

The consumer group consisted of 220 participants, recruited through the online platform Prolific, all of whom resided in the Netherlands. From an initial sample of 242 respondents, 22 were excluded due to failed screening questions or exceeding the time limit for survey completion. The consumer group was largely composed of Dutch nationals (65%). Participants belonging to the consumer group on average completed the questionnaire within 18 minutes. They received financial compensation according to Prolific standards.

The company and expert groups included 92 participants, retained after removing incomplete responses from an initial 121 recruited. The final company sample included 33 participants with an average of 14 years of professional experience. The final expert sample included 59 participants with an average of 12 years of professional experience. Both company and expert participants were recruited through the authors' networks and were contacted using direct mail, social media (e.g., LinkedIn), and mailing lists. We invited participants with expertise in the food domain (e.g., food technology, nutrition, food product development, food design, food policy, food marketing), consumer behaviour, or design (e.g., social design, systemic design). Potential participants received an invitation that contained a link to the Qualtrics questionnaire. They did not receive financial compensation.

Both company and expert participants represented expertise primarily in design (58%), consumer behaviour (56%), (food) product development (54%), and food technology and nutrition (48%). The company representatives were mainly involved in food production (39%), processing and manufacturing (33%), and marketing (27%). The company and expert group participants were generally older and included slightly higher female representation than the consumer group. Additionally, they spent approximately twice as long to complete the questionnaire than consumers (~41 minutes).

5.2 Interventions

In this study, participants evaluated design interventions described in drawings and a narrative story, which served as the stimuli for hypothesis testing. Seven sets of proposed transition design interventions were evaluated, each consisting of three variations of product-service systems (PSSs), planned for phased implementation over time (Figure 5)—the present (Time 1), near future (Time 2), or far future (Time 3). These intervention sets were designed by the authors (three with a background in

design and the fourth with a background in sensory food experience) and visualised by a research assistant (a graduate student in Integrated Product Design at TU Delft). Illustrations of the 21 proposed interventions were accompanied by short narratives, on average 206 words long (word range 137–306), describing a person using the intervention and encountering its attributes and benefits by taking different actions in a specific context of use. The narratives provide a sequence of events in chronological order, which enhances the degree of realism of the described situation, allowing participants to imagine their own prospective engagement (Green & Brock, 2000; Shapiro et al., 2010). The 21 narratives were developed by the authors, who carefully considered factors influencing perceived realism, such as the inclusion of concrete details, familiar settings, and the logical flow of events. The first author is a native English speaker, and the co-authors are fluent in both Dutch and English, which ensured that the narratives would be comprehensible to non-native English-speaking participants, including international and Dutch individuals living in the Netherlands. An example narrative and its corresponding intervention are provided in Appendix B; the full set of materials is available in Appendix E.

5.3 Procedure and Measures

The questionnaire was developed using a Qualtrics survey and administered to the three participant groups. These three groups followed two procedures: one designed for consumer participants and one for company and expert participants. The procedure was largely similar for both groups, with some variations in background questions and evaluation questions for the interventions and some additional questions for the portfolio.

After providing informed consent, all participants were asked if they were comfortable reading and understanding English, and those who answered negatively were excluded from the study. Additionally, participants in the consumer group were asked whether they currently lived in the Netherlands, and those who responded negatively were removed from the study. For the consumer group, the questionnaire proceeded directly to the main survey. Participants in the company and expert groups were first asked to provide additional information regarding their professional backgrounds. They selected from various options, such as working in the food supply chain, conducting research and education, or developing government policy. Participants were asked about their area of expertise, years of experience, and the geographic region in which their activities took place. Company participants also indicated the role of their company in the food system (see Appendix A).

Subsequent questions were rated on a 7-point response scale (1=strongly disagree, 2=disagree, 3=somewhat disagree, 4=neither agree nor disagree, 5=somewhat agree, 6=agree, 7=strongly agree) unless otherwise specified. All participants were then instructed to read seven stories, each describing one of the PSS variations within the intervention sets. Each story included a drawing of the intervention described. For the consumer group, participants answered ten questions after reading each story. Eight of these questions were rated on the response scale described above (i.e., “I can see myself using this innovation,” “It would be attractive for a company to develop an innovation like this,” “This innovation is a new and creative solution to the problem of food waste,” “This innovation will contribute to minimising food waste,” “This innovation will contribute to making consumption patterns more flexible,” “This innovation stimulates [individual behaviour A],” “This innovation stimulates [individual behaviour B],” “This story is believable”). See Appendix C, Table C2, for

the individual behaviours outlined for each intervention set. The ninth question was a categorical response (yes/no/maybe) (“Do you think this innovation will (eventually) be available to consumers?”), and the tenth question was rated on a linear visual analogue scale running from 0 to 20 years (“How many years before this innovation will be available to consumers?”).

The company and expert participants answered similar questions but focused on their professional perspectives. Most of the questions were identical, with the first two items being rephrased as “The innovation is something I can see consumers using” and “It would be attractive for a company to contribute to developing an innovation like this.” The question items were always presented in the same order as indicated above. After evaluating each intervention, participants were provided with an open question to add any additional comments. For consumers, an attention check was randomly inserted between the intervention evaluations in the questionnaire.

After evaluating all seven innovations, the company and expert participants were asked to rate the extent to which the portfolio of innovations demonstrated five specific qualities (i.e., diversity, coherence, complementarity, reinforcement and synergy) on a 7-point response scale (1=far too little, 2=moderately too little, 3=slightly too little, 4=neither too much nor too little, 5=slightly too much, 6=moderately too much, 7=far too much). These additional questions were not posed to consumers because evaluating portfolio dynamics requires a systemic perspective and specialised domain knowledge that is typically more aligned with the expertise of companies and domain experts. Finally, both groups were asked to report their gender and age.

5.4 Data Analysis

To examine how participants evaluated the interventions in terms of desirability, plausibility, and networkedness, we conducted a factorial analysis of variance (ANOVA) of the quantitative survey responses. The analysis focused on comparing mean responses across participant groups to assess how the proposed interventions were perceived in relation to their potential contributions to systemic change. To complement this, we reviewed open-ended responses to explore how participants’ reasoning could help interpret the quantitative results.

The mixed factorial design included both between- and within-subjects factors. The between-subjects factor was the Participant group (three levels: consumer, company, expert), and the within-subjects factors were Intervention Set (seven levels: waste bins, use-me-later tools, freezer integration, frozen ingredients, consumption boxes, assessment labels, ingredient-less recipes), and Time (three levels: now, near future, far future). Descriptive statistics (means and standard errors) were calculated for all conditions. Inferential analyses were conducted using ANOVA to examine the main and interaction effects of Participant Group, Intervention Set, and Time on perceived intervention effectiveness. Tests among the three product–service system (PSSs) variants within a single set always involved between-subjects comparisons. Tests across different sets involved both within- and between-subjects elements since interventions from multiple sets were randomly assigned to each participant. Consequently, the experimental structure did not permit the isolation of repeated-measures effects from between-subjects variance. Therefore, all comparisons were treated as between-subjects in the statistical analysis.

All quantitative analyses were performed using SPSS (version 28). Reported

results include F-values, p-values, and partial η^2 as a measure of effect size. Where significant effects were observed, Bonferroni-corrected pairwise comparisons of means were used to account for multiple testing. In comparisons of means for separate PSSs in the different participant groups, we used observed means and standard errors rather than marginal means with pooled error estimates. A detailed mapping of survey questions to their corresponding dependent variables is provided in Appendix C, Table C1.

In addition to the quantitative analysis, we reviewed open-ended responses to identify recurring themes that contextualised participants' evaluations. While these qualitative data were not systematically coded, all open responses were exported into Excel, organised by Set and PSS, and colour-coded into common themes. This revealed patterns such as perceived effort, convenience, personalisation, and ethical considerations. These insights supported the interpretation of the quantitative findings and offered a deeper understanding of how different actor groups perceived the interventions.

6. Results

To structure the presentation of our results, we follow the sequence of the hypotheses formulated in Section 6 concerning desirability, plausibility, and networkedness. Prior to this, we assessed whether participants perceived the narratives as believable to ensure that the use of narratives was meaningful and comprehensible from the participants' perspective.

6.1 Check on Control Variables

On average, participants across all groups rated the believability of the stories above the neutral midpoint of the 7-point scale ($M = 5.05$), indicating general agreement that the scenarios were believable. This pattern held consistently across participant groups, with group mean ratings ranging from 4.89 to 5.11. Believability scores (item 1 in Table C1) for the 21 individual PSSs ranged more widely (from 3.73 to 5.92), but all were at or above the midpoint. Therefore, participants rated the PSSs at least close to 4 (=do not agree nor disagree) up to almost 6 (=agree) on the believability item, suggesting that no intervention was broadly rejected as implausible. These results confirm that the narrative stimuli were sufficiently credible to serve as the basis for further analysis.

6.2 Desirability

To assess the overall desirability of the interventions, we combined participants' ratings of Value (items 2 and 3) and Innovativeness (item 4) into a single composite score. These two dimensions were both conceptually aligned and statistically correlated, with the three-item scale demonstrating satisfactory internal consistency (Cronbach's $\alpha = 0.746$; see Table 1). Across all actor groups, mean desirability ratings were above the midpoint of the 7-point scale, with an overall portfolio mean of 4.88. No statistically significant differences were found in ratings between consumers ($M=4.91$), companies ($M=4.90$), and experts ($M=4.75$), indicating a broad agreement that the interventions were desirable. These findings support Hypothesis 1.

Similar patterns emerged when examining Value and Innovativeness as separate

dimensions (Table 1). All mean ratings for value were consistently high across groups, and although innovativeness scores were slightly lower, all remained significantly above the neutral midpoint (based on mean \pm 2SE). This reinforces the conclusion that participants viewed the interventions not only as valuable but also as innovative.

When looking at the 21 PSSs, mean desirability ratings showed similar variation but followed a consistent pattern across the different actor groups. Consumer mean ratings ranged from 4.10 to 5.59, companies from 3.94 to 5.80, and experts from 4.10 to 5.59 (see Appendix D). Only 2% of the PSSs received means below 4, providing further support for the conclusion that the interventions were broadly desirable. Therefore, these results also generally confirm H1.

A detailed mapping of survey questions to their corresponding dependent variables is provided in Table 1 with Appendix C, Table C1.

Table 1. Observed mean ratings and standard errors (SE) for Believability, Desirability, and Plausibility for the different groups at the portfolio level.

Construct	Item (see Table C2)	Cronbach's Alpha	Consumers (n = 220)		Companies (n = 33)		Experts (n = 59)	
			mean	SE	mean	SE	mean	SE
Believable	1	-	5.11	0.04	5.00	0.10	4.89	0.08
Desirability	2-4	0.75	4.91	0.03	4.90	0.09	4.75	0.06
Value	2,3	0.76	4.98	0.04	5.00	0.09	4.87	0.07
Innovativeness	4	-	4.77	0.04	4.71	0.12	4.53	0.08
Plausibility	5-8	0.85	5.26	0.03	5.26	0.03	5.03	0.06
Systemic change	5,6	0.76	5.00	0.03	5.00	0.09	4.78	0.06
Behavioural effect	7,8	0.82	5.52	0.03	5.61	0.08	5.28	0.06

While desirability was generally high across the portfolio, some interventions stood out as notably more or less appealing to different actor groups. The “Countertop Waste Bin” (PSS 1) consistently received the lowest mean ratings, particularly among experts (3.51), while the “Fridge-Freezer Drawers” (PSS 7) also scored relatively low, especially among companies (M = 4.22) and consumers (M = 4.35). On the other hand, “Food Life Extending Tools” (PSS 5) was considered to be most desirable, particularly by companies (5.80), while consumers (5.34) and experts (4.81) assessed it as moderately desirable. “Preservation pods” (PSS 6) also received high ratings from consumers (5.59), with companies (5.10) and experts (4.91) indicating moderate desirability (see Appendix D). One PSS—“Minimalist Labels” (PSS 18)—elicited the most divergent responses. Experts rated it relatively high (M=4.96), while companies (3.94) and consumers (4.38) were less enthusiastic.

6.2.1 Innovativeness

Participants’ perceptions of innovativeness generally increased across the three time points (from Time 1 to Time 2) and remained high at Time 3. To test this pattern (Hypothesis 2), we conducted an analysis of variance (ANOVA) to compare mean innovativeness ratings (item 4) over time with Set, Time, and Participant groups as between-subjects factors. As expected, the results indicated a significant main effect

of Time at the portfolio level [$F(2, 2121) = 22.77, p < 0.001, \eta^2 = 0.021$], showing that ratings increased from Time 1 ($M=4.26$) to Time 2 ($M=4.95$), then slightly decreased at Time 3 ($M=4.83$), though no significant difference was observed between Time 2 and Time 3 ($p > 0.20$). These results indicate that participants viewed future-oriented interventions as more innovative, though perceptions levelled off between the near and far future.

We also examined differences in perceived innovativeness across actor groups. A small but statistically significant main effect of Participant Group was found [$F(2, 2121) = 5.36, p = 0.005, \eta^2 = 0.005$]. Experts found the 21 PSSs to be less innovative (4.52) than companies (4.73) and consumers (4.77). No two-way interaction effect between Group and Time was observed [$p = 0.485$] (see Table 2), suggesting that while experts were generally more cautious in their assessments, the overall trend of increasing innovativeness over time was consistent across all groups.

Perceptions of innovativeness over time varied by intervention set. While most sets followed the general trend of increasing ratings from Time 1 to Time 3, some deviated from this pattern. While ratings increased with time for most sets, the “Ingredient-less Recipes” showed little change with time, while the ‘Assessment Labels’ saw ratings drop over time. A two-way ANOVA revealed a significant main effect of intervention Set [$F(6, 2121) = 7.36, p < 0.001, \eta^2 = 0.020$], as well as a significant Set x Time interaction [$F(12, 2121) = 4.38, p < 0.001, \eta^2 = 0.024$]. This two-way interaction indicates that the Time effect is different for the different intervention sets (Figure 6). To explore these differences, we conducted separate two-way ANOVAs (Time x Participant Group) for each set. Most sets showed the expected pattern: lower innovativeness at Time 1, rising at Time 2, and remaining steady or slightly declining for Time 3. However, for the “Ingredient-less Recipes” set, the time effect just missed statistical significance [$F(2, 303) = 2.99, p = 0.052, \eta^2 = 0.019$], with means varying from 4.15 (Time 3) to 4.85 (Time 2). Additionally, a notable deviation was found in the ‘Assessment Labels’ set, where perceived innovativeness significantly decreased over time [$F(2, 303) = 4.03, p = 0.019, \eta^2 = 0.026$] from 5.10 at Time 1, to 4.88 at Time 2, to 4.34 at Time 3. Pairwise comparisons with Bonferroni correction revealed that the difference detected between Time 1 and Time 3 was significant ($p = 0.018$), while the difference between Time 1 and Time 2 was not ($p = 1.000$).

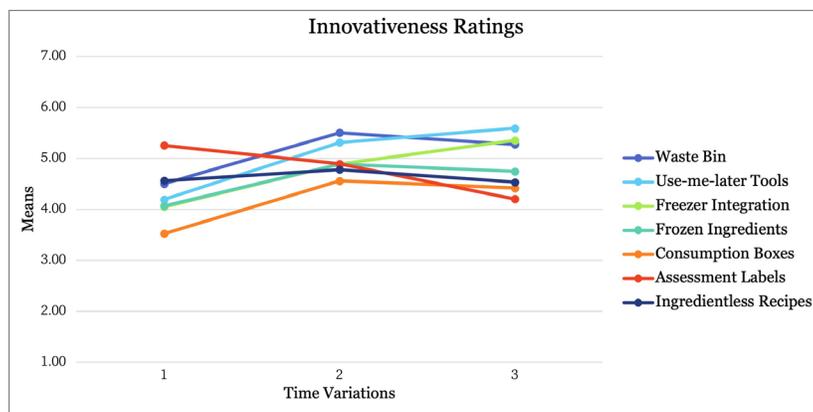


Figure 6. Mean innovativeness ratings over time for the seven sets and 21 PSSs. Responses varied from 1=strongly disagree to 7=strongly agree.

6.2.2 Intervention availability

To assess expectations about whether the proposed interventions would eventually become available to consumers, we asked participants to indicate both the likelihood of availability (“yes,” “maybe,” “no”) (item 9 in Table C1) and their estimated time frame on a scale of 0–20 years (item 10 in Table C1), thereby addressing Hypothesis 3. Overall, we found that consumers expressed greater confidence in the future availability of the interventions compared to companies and experts. Specifically, in the proportion of “yes” responses, 57% of consumers believed the interventions would become available, while this belief was shared by only 49% of company representatives and 50% of experts. In contrast, the “maybe” responses were more common among companies (37%) and experts (36%) than consumers (30%). The percentages of people who indicated that a PSS would not become available were similar for the three participant groups (12% for consumers, 14% for companies, and 14% for experts). A Kruskal-Wallis test for independent samples revealed that these differences in response distributions among the three groups were statistically significant [$H(2) = 9.36, p = 0.009$]. Additionally, post-hoc pairwise comparisons showed that consumers differed significantly from both companies and experts [$p < 0.05$]. These findings highlight differing perceptions across actor groups, with consumers more inclined to see the interventions as achievable, while professionals in the field expressed greater uncertainty.

If participants answered “no” for item 9, they were not prompted to enter an estimate for the number of years before the intervention would be introduced (item 10). Since the percentages were similar in the three groups, we decided to continue our analyses for item 10 without any need for further corrections. Overall, participants anticipated a longer wait for interventions to reach the market the further they were positioned in the future (see Table D1). An ANOVA of item 10 confirmed a significant main Time effect [$F(2, 1844) = 41.66, p < 0.001, \eta^2 = 0.043$], alongside a significant main Set effect [$F(6, 1844) = 28.77, p < 0.001, \eta^2 = 0.086$] and a significant Time x Set interaction [$F(12, 1844) = 6.91, p < 0.001, \eta^2 = 0.043$]. Average time estimates increased across the three time points from 2.57 years for Time 1 to 3.92 for Time 2 and 4.73 for Time 3. These differences were statistically significant in pairwise comparisons using Bonferroni corrections [$p < 0.01$]. No main effects of the Participant group [$p > 0.20$] were found, suggesting consistent expectations across consumers, companies, and experts.

To explore the interaction between time and intervention type, we analysed each intervention set separately using two-way ANOVAs. For the first five sets in Figure 6, participants consistently estimated longer timeframes as the interventions moved from present-day (Time 1) to far future (Time 3), with significant time effects in all cases [$p < 0.01; 0.037 \leq \eta^2 \leq 0.163$]. In paired comparisons with Bonferroni correction, Time 1 differed significantly from Time 3 in all five sets ($p < 0.01$) and in three cases also from Time 2 ($p < 0.01$). Only one set showed a significant difference between Time 2 and Time 3 ($p < 0.01$). For the final two intervention sets, no significant time effects were found [$p > 0.10; \eta^2 \leq 0.016$], indicating stable expectations across time frames.

Table 2. Observed mean ratings, standard errors, and p-values for each participant group over time for Value, Innovativeness, and Plausibility. Responses varied from 1=strongly disagree to 7=strongly agree.

Construct	Time 1		Time 2		Time 3		F Test
	Means	SE	Means	SE	Means	SE	p-value
Value							
Consumers (n=220)	4.90	0.06	5.03	0.06	5.00	0.06	0.334
Companies (n=33)	4.90	0.18	5.13	0.15	4.99	0.16	0.610
Experts (n=59)	4.97	0.12	4.66	0.12	4.99	0.10	0.067
Innovativeness							
Consumers (n=220)	4.36	0.07	5.05	0.07	4.92	0.07	< 0.001
Companies (n=33)	4.25	0.21	5.14	0.18	4.82	0.20	0.005
Experts (n=59)	4.18	0.15	4.65	0.12	4.75	0.12	0.006
Plausibility							
Consumers (n=220)	5.03	0.05	5.44	0.05	5.31	0.05	< 0.001
Companies (n=33)	5.08	0.14	5.53	0.12	5.35	0.14	0.057
Experts (n=59)	4.93	0.11	4.91	0.09	5.26	0.09	0.020

6.2.3 Qualitative feedback on desirability

To further explore participants’ perceptions of desirability, we analysed their open-ended responses to the interventions. Overall, participants’ perceptions of desirability were shaped not only by perceived benefits but also by anticipated barriers related to effort, trust, and relevance. Many participants highlighted convenience and personalisation as important qualities that made interventions desirable. At the same time, concerns emerged about data privacy, particularly in relation to the “Waste Bins” and “Consumption Boxes” sets, which were perceived to involve data collection and sharing. Additionally, intervention sets, such as the “Ingredient-less Recipes” or “Assessment Labels,” were described as cognitively demanding, requiring planning, decision-making, and interaction with new technologies. Participants found these factors off-putting. Practical concerns also influenced perceived desirability. The “Fridge-Freezer Drawers” (PSS 7) were viewed as energy-intensive, while “Dissolvable Packaging” (PSS 9) raised concerns about food safety. Additionally, some participants felt that intervention sets like the “Consumption Boxes” and “Frozen Ingredients” lacked novelty, noting their similarity to other products on the market.

6.3 Plausibility

Overall, participants generally viewed the interventions as plausible, supporting Hypothesis 4. We assessed this using the means of items 5 to 8 ($\alpha = 0.845$). At the portfolio level, average plausibility ratings were relatively high ($M = 5.22$) (see Table 1). Additionally, a significant main effect of Participant group emerged [$F(2, 2121) = 6.16, p = 0.002, \eta^2 = 0.006$], with consumers ($M = 5.26$) and companies ($M = 5.28$) rating the portfolio as more plausible than experts ($M = 5.05$). Paired comparisons with Bonferroni correction confirmed these differences to be statistically significant

($p < 0.05$). Across the 21 PSSs, the mean ratings for each group followed a similar pattern: consumer ratings ranging from 4.62 to 5.83, companies from 4.36 to 5.89, and experts from 4.06 to 5.69 (see Table D1).

Some interventions (the individual PSSs) were consistently seen as more plausible than others. The “Fridge-Freezer Drawers” (PSS 7) received the lowest mean ratings from companies ($M = 4.36$) and consumers ($M = 4.62$), while experts rated it slightly more plausible ($M = 4.79$). The “Countertop Waste Bin” (PSS 1) was rated as least plausible by experts ($M = 4.06$) and moderately plausible by companies ($M = 4.77$) and consumers ($M = 4.77$). On the other hand, the “Food Life Extending Tools” (PSS 5) was rated most plausible by companies ($M = 5.80$) and consumers ($M = 5.67$), though experts gave it a slightly lower rating ($M = 4.95$). Other PSSs with high overall ratings were the “Ingredient-less Recipes” (PSS 19) and the “Ingredient-less Menus” (PSS 20) (see Appendix D). Overall, these findings support the general conclusion that, while ratings varied by actor group, the proposed interventions were broadly considered plausible, thereby confirming Hypothesis 4.

Further analysis distinguished between two related aspects of plausibility: 1) the contribution to the systemic challenge to reduce food waste and 2) the intended behavioural effects on individual and systems-level flexibility (Table 1). Although these aspects were highly correlated and were combined into a single indicator of perceived plausibility for hypothesis testing, the mean values diverged. Participants rated the contribution to systemic change (items 5 and 6) as less plausible than the intended behavioural effects (items 7 and 8) (mean difference 0.525, $p < 0.001$). This suggests that participants found the interventions’ potential to change individual behaviour more plausible than their ability to drive large-scale systemic change. See Appendix D for the means and standard errors (SE) for all 21 PSSs for each participant group.

6.3.1 Plausibility over time

We explored whether participants’ perceptions of plausibility changed depending on how far into the future an intervention was positioned (Hypothesis 5). We found that perceived plausibility increased from Time 1 to Time 3 for all groups, indicating an increase in expected impact for the more futuristic interventions.

Plausibility was measured using items 5 to 8 ($\alpha = 0.846$), and mean scores were compared across three time points. A significant main Time effect emerged [$F(2, 2121) = 8.52, p < 0.001, \eta^2 = 0.008$], indicating that, overall, participants rated intervention sets further into the future as more plausible. However, this trend differed across groups, as indicated by a significant Time x Participant group interaction [$F(4, 2121) = 3.01, p = 0.017, \eta^2 = 0.006$] (see Table 2). For consumers, plausibility ratings increased significantly over time [$F(2, 1519) = 17.72, p < 0.001, \eta^2 = 0.023$], with the lowest ratings at Time 1 (5.04) compared to Time 2 (5.49) and Time 3 (5.32) [i]. The difference between Time 2 and Time 3 ($p > 0.20$) was not statistically significant, suggesting a plateau in perceived plausibility beyond the near future (Time 2). A similar trend was observed for companies. Company mean ratings also increased from Time 1 ($M = 5.04$) to Time 2 ($M = 5.48$) and Time 3 ($M = 5.32$), but this effect just failed to reach statistical significance [$F(2, 210) = 2.75, p = 0.066, \eta^2 = 0.026$]. Among experts, plausibility scores rose more gradually. No significant difference was observed between Time 1 ($M = 4.95$) and Time 2 ($M = 4.93$), but ratings significantly increased at Time 3 ($M = 5.26$), [$F(2, 392) = 3.95, p = 0.020, \eta^2 =$

0.020], with an increase from Time 2 to Time 3 reaching statistical significance ($p < 0.05$).

Taken together, these results suggest that participants in all groups perceived far-future interventions (Time 3, $M = 5.26 - 5.32$) as more plausible than present-day ones (Time 1, $M = 4.95 - 5.04$). This difference was statistically significant for consumers and experts and just failed to reach significance for the companies, possibly due to the smaller sample size. This suggests that plausibility increased for all groups between Time 1 and Time 3. However, groups differed in how they evaluated near-future (Time 2) interventions, with experts generally less convinced by their plausibility than consumers and company representatives.

6.3.2 Mediation of plausibility

We examined whether participants' belief that interventions could reduce food waste was partly explained by how much those interventions were expected to increase behavioural flexibility (Hypothesis 6). Using the Hayes PROCESS macro version 4.2 in SPSS (Model 4), we conducted a mediation analysis to investigate the interrelationships among the components of plausibility: We tested whether the specific behavioural effects (items 7 and 8) of the different interventions led to more flexibility (item 6) and whether this flexibility increase was responsible for the expected decrease of food waste (item 5), or whether there was another path, independent of the effect of flexibility on food waste.

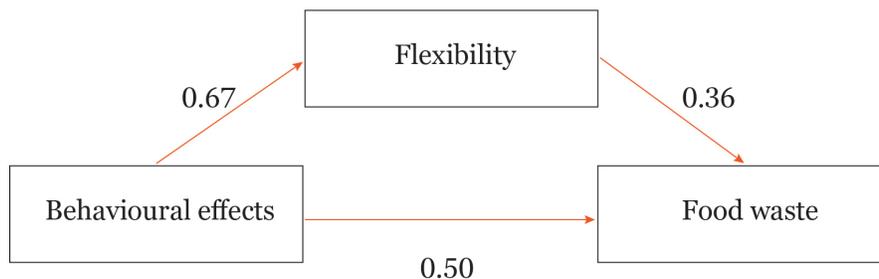


Figure 7. Mediation analysis for the effect of flexibility on reducing food waste on the portfolio level for consumer responses. Based on Hayes Process Model 4.

For all three actor groups—consumers, companies, and experts—the analysis confirmed that behavioural flexibility partly mediated the relationship between an intervention's behavioural effects and its perceived ability to reduce food waste. For the consumer data at the portfolio level (Figure 7), all paths in the mediation model were statistically significant ($p < .001$), supporting the role of flexibility as a mediator between behavioural effects and expected reductions in food waste. The indirect effect through flexibility was significant, with a bootstrap coefficient of 0.24 ($SE = 0.02$, 95% CI [0.2053, 0.2841]). As shown in Table 3, similar analyses conducted for companies and experts yielded comparable results: all path coefficients, including the indirect effects, were significant. These findings indicate a consistent pattern across actor groups. Because both the direct and indirect effects were significant in each case, we interpret this as partial mediation—suggesting that increased behavioural flexibility partly explains why participants believe the interventions could help reduce food waste while also recognising that other mechanisms are likely at play.

Table 3. Mediation analyses for the portfolio level for the different participant groups. Based on Hayes Process Model 4.

	Behavioural effects - Food waste		Behavioural effects - Flexibility		Flexibility – Food Waste		Combined indirect effect	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	Bootstrap SE
Consumers	0.50	0.02	0.67	0.03	0.36	0.02	0.24	0.02
Companies	0.39	0.07	0.73	0.07	0.35	0.05	0.26	0.05
Experts	0.39	0.05	0.65	0.05	0.36	0.04	0.24	0.03

6.3.3 Qualitative feedback on plausibility

To deepen our understanding of how participants perceived the plausibility of the interventions, we reviewed their open-ended responses. Overall, participants’ perceptions of plausibility were shaped not only by technological feasibility but also by broader concerns around implementation, unintended consequences, and the readiness of existing systems to adopt such interventions.

We found that interventions based on familiar or existing technologies, like the “Preservation Duo” (PSS 4) and “Frozen Meals” (PSS 10), were generally seen as technically feasible and market-ready with minor adjustments. In contrast, interventions involving advanced automation, AI integration, and novel materials like the “Dissolvable Packaging” (PSS 12) and “Smart Kitchen System” (PSS 3) elicited more caution. Participants questioned the technical readiness of these interventions and pointed to long development timelines, high costs, and implementation challenges as barriers. Several participants also raised concerns about unintended consequences, such as increased food waste due to automation reliance or potential declines in food literacy. These doubts were especially pronounced for far future interventions (Time 3), where participants reported scepticism about whether current systems could realistically support such interventions.

6.4 Networkedness of Interventions

To evaluate how well the interventions worked together as a portfolio (Hypothesis 7), company representatives and experts rated the overall networkedness of the portfolio across five dimensions: diversity, complementarity, synergy, reinforcement, and coherence (items 11 to 15 in Table C1). On average, the mean responses across all dimensions hovered around the midpoint of the scale (=4), which represented the optimum balance of the scale (neither too much nor too little). As there were no significant differences between the companies and experts [$p > 0.20$], we aggregated the data and only presented the overall means here.

Ratings for all dimensions were as follows: diversity (item 11)($M = 3.82$, $SE = 0.08$), complementarity (item 12)($M = 3.80$, $SE = 0.11$), synergy (item 13)($M = 3.89$, $SE = 0.15$), reinforcement (item 14)($M = 3.75$, $SE = 0.09$), and coherence (item 15)($M = 3.95$, $SE = 0.08$). This suggests that the intervention portfolio was generally perceived as networked. However, in their comments, some participants expressed difficulty in distinguishing between closely related dimensions, such as synergy versus complementarity. Additionally, they noted that having the interventions displayed on-screen during the portfolio assessment and briefly explaining how they could work together would have been beneficial.

7. Discussion

Assessing the effectiveness of interventions remains an understudied activity in transition design research and practice. This is perhaps not completely surprising, given the field's relative youth and the nature of the challenges it engages with—challenges that span multiple scales and timeframes, involve diverse actor networks, and require reflexivity and portfolio-based thinking (Dorst, 2015; Goss et al., 2025d). Moreover, transition design addresses societal issues whose outcomes are inherently uncertain and cannot be fully predicted or controlled. Impacts tend to emerge over time, which calls for evaluative approaches that support learning and adaptation (Patton, 2010; van den Bosch, 2010). The present study addresses this gap in the transition design field by proposing a conceptual framework that connects five essential transition design activities—navigating scales from micro to macro-level systems; considering temporality from present to far future; engaging and repositioning actors from individuals to networks; framing and designing from single solutions to portfolios; and practising reflexivity across activities and outcomes—to three qualities of its outcomes: desirability, plausibility, and networkedness (see Figure 1).

To empirically investigate this framework, we developed specific hypotheses examining these three qualities and conducted a mixed-methods study evaluating a portfolio of seven proposed intervention sets comprising 21 product-service systems (PSSs). The PSSs resulted from a transition design process to reduce food waste in the Netherlands. Our evaluation engaged 312 participants across key actor groups (consumers, companies, and experts), with each participant assessing seven innovations varying in degree of innovativeness and how they evoke behavioural changes. Through a questionnaire combining quantitative scales with open-ended qualitative questions, we gathered rich insights into actor perceptions. In what follows, we reflect upon the approach in the transition design process and the evaluations of the outcomes, discussing its relevance for transition design methodology and practice.

7.1 The Transition Design Process and Outcomes

Our results affirm that our transition design process successfully yielded proposed interventions that meet the needs of various actors (consumers, companies, experts) and are likely to drive both individual and systemic behavioural changes towards food waste reduction. Following their evaluation, the proposed interventions were found to be desirable ($M = 4.88$) and plausible ($M = 5.22$), with 19 out of 21 PSSs scoring 4.00 or higher on a 7-point scale for these metrics. These results affirm Hypotheses 1 and 4 related to intervention desirability and plausibility. The interventions also demonstrated a substantial degree of networkedness, as their mean ratings for diversity, complementarity, synergy, reinforcement, and coherence were close to a mean of 4, suggesting almost optimal interconnectedness within the portfolio and affirming Hypothesis 7. Additionally, the interventions were perceived to prospectively lead to a reduction of food waste to some extent by supporting flexible behaviours (Hypothesis 6), a finding which further supports their potential for systemic impact. This is the first confirmation that engaging in the five activities as described in our transition design framework can lead to desirable, plausible and networked outcomes.

7.1.1 Temporal dynamics in desirability and plausibility

As expected, innovativeness (H2) was rated lowest for most of the intervention sets at Time 1. Differences between the Time 2 and Time 3 interventions were not significant (Table 2). This indicates that participants perceived present-day interventions (Time 1) as clearly less innovative than those for the near future (Time 2) and far future (Time 3). Participants reported smaller differences between Time 2 and Time 3, and in several cases, the mean scores for Time 2 were higher than those for Time 3. We did not specify any expectation for time effects for the value dimension of desirability, and indeed, Table 2 shows that the perceived values of the PSSs are not linked to a time horizon.

Contrary to innovativeness, we hypothesised plausibility ratings to be equal at all moments in time (H5). This was because the variations of PSSs within each set were designed to reflect its evolution over time, meaning that all three PSS within the set should be equally plausible in the context in which they would be implemented. However, the plausibility ratings followed a similar pattern to the innovativeness ratings, with all participants giving the lowest plausibility ratings to present-day interventions (Time 1). Plausibility means at Time 1 were consistently lower than those at Time 3, with the means at Time 2 being similar to Time 3 for consumers and companies and means at Time 2 being similar to Time 1 for experts (Table 2). This indicates that plausibility ratings largely followed the same pattern as those for innovativeness.

While the differences in mean innovativeness ratings between Time 1 and Time 3 were approximately 0.6 on the 7-point scale, the differences in plausibility ratings were about 0.3. As plausibility reflects the participants' confidence that the proposed interventions will result in the desired behavioural changes—in other words, transforming the system through increasing flexibility and reducing food waste—the perceived increase in plausibility with time reflects the designers' success in proposing effective interventions. The attenuated increase in rating possibly shows participants' awareness of the practical limitations associated with the more innovative concepts. While participants acknowledged an increase in the innovativeness of proposed interventions at Time 3, they may have tempered their plausibility ratings due to scepticism with respect to their possible implementation. Alternatively, participants possibly expect that not all interventions and associated behaviours are effective in reducing food waste and thus contribute only partially to the desired changes. Therefore, we might assume that compromises arise between innovativeness and plausibility over time. Nevertheless, these results generally indicate a higher confidence for interventions that offer new ways of performing daily practices (Time 2 and 3 interventions) rather than simply optimising current practices (Time 1 interventions).

The temporal distinctions observed in the ratings highlight several research opportunities, particularly concerning the timing at which different actors are involved in transition design processes. Interestingly, our experts appear to have more confidence in the effects of the more radical futuristic interventions (Time 3), while they consider present and near future interventions to be equally (and less) plausible to lead to transformation. Hence, experts are more likely to contribute their knowledge and expertise most effectively during the early conceptualisation phases, where their preference for bold, systemic changes through interventions can be strategised. Conversely, securing company buy-in and attracting consumer interest may require interventions that move only slightly beyond incremental innovation

(Time 2), as the uncertainty of implementation and adoption over longer timeframes become harder to imagine.

When considering the time effects for the seven sets, the perceived innovativeness and expected time to market did not increase from Time 1 to Time 3 for the sets “Assessment labels” and “Ingredient-less recipes.” Interestingly, these sets provided interventions that were relatively low-tech compared to the others. This suggests that participants tended to equate innovativeness with technical challenge or sophistication. In that respect, their perception deviated from the designers’ intended timeframe categorisations, which also considered the challenge to educate consumers on, for example, food quality (PSS 18) and cooking techniques (PSS 21).

7.1.2 Individual versus systemic behavioural perceptions

The intervention sets were designed to stimulate waste-free and flexible behaviour in daily life while driving broader systemic changes (see Section 3). The results, however, showed a statistically higher perceived likelihood that the intended individual behavioural changes would occur compared to the systemic change, i.e., flexibility and food waste reduction (Table 1). This disparity may be due to several factors. First, designers’ human-centred expertise, which prioritises people’s needs, aspirations, and daily routines, likely makes participants feel more confident in the interventions’ potential for immediate behavioural impact, while the potential systemic outcomes remain less apparent (van der Bijl-Brouwer & Dorst, 2017). Second, systemic outcomes such as “flexibility” and “food waste reduction” may seem more abstract and distant compared to individual behavioural change, such as keeping partially used food for later use, which shows more immediacy and personal relevance. According to psychological distance theory, distant concepts are inherently more challenging to assess, potentially explaining these differences in ratings (Trope & Liberman, 2010). Communicating systemic impacts requires greater depth than what a single concept drawing or short narrative of a user practice can offer (Goss et al., 2024; Sevaldson, 2022). Although designers are exploring various methods to integrally communicate different systemic effects—such as through scenarios (e.g., Boehnert and Alexander (2025)), giga-mapping (Sevaldson, 2022), and role-playing (e.g., Formo Hay et al. (2024))—further exploration is needed into how these methods can inform decision-making within transition design processes and effectively engage and communicate with diverse actors.

7.2 Assessing Individual PSSs

In the present study, data was collected on all 21 PSSs. However, our primary interest was in the results of the portfolio, which comprised all seven sets of interventions relating to different aspects of the proposed practice. This focus aligned with our research question and the fact that the portfolio development was a main outcome of the transition design process undertaken (see Section 3). Consequently, the analysis prioritised how the individual PSSs integrated within their respective intervention sets and how these sets collectively formed a networked portfolio rather than examining individual PSSs in isolation. Future analyses could explore the data at the level of individual PSSs to identify significant differences within and between sets or among actor groups.

7.2.1 Integrating feasibility and viability in transition design processes

In developing the portfolio of 21 interventions through the transition design process outlined in Section 3 and evaluated in the present study, technological feasibility and financial viability were intentionally deprioritised by the designers. This choice was made to avoid constraining the reimagining of new practices and systems and to generate a diverse portfolio of interventions (Gaziulusoy & Ryan, 2017b; Goss et al., 2024; Kazakci et al., 2015). However, the written comments indicated that participants assigning lower scores to specific sets raised concerns about technical feasibility and financial viability, particularly regarding data privacy and the originality of certain PSSs. For instance, participants noted that some PSSs (e.g., the three comprising the “Consumption box” set) lacked new business opportunities, given their similarity to existing solutions. This concern about originality, however, overlooks that replicating effective interventions is essential in transitions as it enables the amplification of proven strategies across the system, a crucial factor in achieving systemic change (Quaggiotto, 2024).

Although feasibility and viability were intentionally deprioritised in the evaluation, participants’ feedback suggests that these practical considerations nevertheless shaped their perceptions of plausibility and desirability. This indicates that future evaluations might benefit from more explicitly integrating assessments of feasibility and viability into study designs while also ensuring that participants are sufficiently informed to evaluate these aspects accurately. While our evaluative framework shares surface similarities with established innovation evaluation models, such as IDEO’s emphasis on desirability, feasibility, and viability, it introduces a crucial distinction. In our approach, plausibility is defined in terms of an intervention’s potential to foster individual and systemic behavioural changes rather than its immediate practical feasibility. This distinction reflects the specific aims of transition design, which seeks not merely to develop new products or services but to reimagine and shift entire systems. As such, future research should carefully consider how and when feasibility and viability assessments are incorporated, ensuring they support, rather than constrain, systemic ambitions.

While evaluation is not new to design, few studies have explored how structured, hypothesis-driven methods might complement more interpretive and participatory forms of assessment within systemic and transition design. This study responds to that gap by demonstrating how design proposals—conceptual in nature and speculative in time—can be meaningfully evaluated through a narrative-based, mixed-methods approach. By revealing patterns in actors’ perceptions of desirability, plausibility, and networkedness, our approach not only offers a way to evaluate early-stage interventions but also contributes to ongoing discourse on the role of empirical evaluation in design research. Rather than displacing qualitative or embedded approaches, this work invites a richer conversation about how diverse evaluative logics can coexist and support the advancement of societal transitions.

7.2.2 The role of qualitative insights in PSSs prioritisation

While the interventions were generally perceived as being desirable, plausible, and networked, the study’s quantitative evaluation exhibited limitations in assessing the unique qualities of the individual PSSs. Although some interventions obtained lower or higher mean responses, most of the means were quite similar and thus provided limited guidance on how to prioritise interventions for further development

(see Appendix D). As such, these results were probably insufficient for effectively narrowing down the selection of interventions. Transition design necessitates not only the development of multiple interventions but also an approach for prioritising and deciding between them to facilitate resource mobilisation and implementation (Irwin, 2018; van den Bosch, 2010). The results of this study suggest that a predominantly quantitative approach may be too prescriptive and normative for evaluation in transition design, as this may result in overlooking factors critical to prioritisation, such as localised barriers, actor motivations, and interdependencies between interventions. The option to add comments to their responses was used regularly, especially among companies and experts, and supported further understanding of the quantitative ratings. Integrating qualitative insights through a stronger mixed-method evaluation approach could offer a more context-sensitive basis for decision-making, guiding transition designers in prioritising and iterating upon interventions while also understanding the conditions necessary for their effective implementation and adoption. A next step for working with the data collected from the present study could be to analyse the qualitative data from the open questions more thoroughly per each PSS to provide more direction for pathways to take but also to guide further studies that investigate the potential of each of the 21 PSSs in more detail, for instance for feasibility and viability.

7.3 Limitations of Study Method for Evaluations

The present study evaluated a portfolio consisting of seven sets of interventions across three different timeframes: present-day (Time 1), near-future (Time 2), and far-future (Time 3). However, participants only assessed one timeframe variation within each set, meaning they did not experience the intended evolution of the practice (“adaptable consumption” as outlined in Section 3). Although evaluating all timeframe variations sequentially within each intervention set was not feasible given constraints in time and cognitive load, this limitation likely affected our results, as more comprehensive evaluation across all timeframe variations might have revealed a greater divergence between interventions.

Our results validate that the transition design process, involving the five core activities, led to a portfolio of networked interventions. Despite this, challenges emerged in evaluating the portfolio, with participants struggling to understand concepts such as complementarity and synergy. Additionally, the lack of prioritisation in our study setup prevented clear decisions on which interventions to advance first. Future evaluations would benefit from a more structured prioritisation method to discern which interventions within the portfolio to pursue, such as ranking. This could also include mapping the interventions to better understand the reinforcing mechanisms between them (Sevaldson, 2022) and/or identifying those that present the greatest learning opportunities (van den Bosch, 2010) to guide decision-making.

The setup faced limitations in recruiting and retaining company representatives and experts due to their busy schedules and competing demands, thus reducing participant diversity. This study relied on social networks to recruit participants without financial incentives, possibly leading to selection bias, as only those with a strong interest in food waste or connections to the authors participated. Additionally, the length and cognitive demands of the study posed further constraints, with company and expert participants engaging in the content for approximately twice as long as consumers. This difference in time investment occurred because experts and company actors invested more time in providing qualitative feedback than

consumers, as shown by the number and lengths of their comments. This time commitment may have influenced participant engagement levels, leading to reduced participation, fewer added comments, and some unfinished questionnaires.

Furthermore, the decision to conduct this study in English and recruit participants via Prolific and the authors' networks was informed primarily by practical considerations, including the working language of the primary researcher, time constraints, and the prevalent use of English in the Netherlands and of targeted expert participants. Since food waste is a universally experienced phenomenon, language was not anticipated to significantly influence participants' conceptual understanding or responses. Nevertheless, while this approach facilitated the recruitment of a diverse range of participants in terms of age and nationality, it may have excluded non-English speakers and/or individuals less comfortable with digital research platforms. This limitation potentially impacts the representativeness and, thus, the generalisability of the findings. Future research could enhance participant inclusivity by administering questionnaires in multiple languages, thereby reaching a broader demographic and further improving the robustness and applicability of the results.

Finally, a limitation of this study lies in the fact that participants did not assess actual interventions but instead evaluated conceptual representations conveyed through illustrations and written narratives. While we made considerable effort to immerse participants in the storyline of a user engaging with the product-service system, this remains different from the experience of interacting with a fully developed product-service system. On the one hand, our presentation method allows for greater imaginative engagement and creative interpretation, which can enhance the perceived potential of the concept and generate valuable suggestions for improvement. It also enabled the exploration of ideas that are not yet technically or practically feasible. On the other hand, evaluating a more tangible and realistic version of the PSSs could yield more concrete insights into their feasibility and viability. Future research could address this by adopting more immersive techniques, such as virtual reality, to increase the realism of the innovation experience during the test. Furthermore, while the use of questionnaires provides valuable information about participants' perceptions, considerations, and intentions, it does not capture actual behaviour. For innovations that may not become available for several years, predicting acceptance is inherently challenging due to uncertainties about the future context of use. In the absence of direct behavioural data, participants' responses offer informed estimations that may, therefore, be the most reliable insights currently attainable.

8. Conclusion

As transition design continues to develop as a field, there is an increasing need for approaches that support both its exploratory and systemic ambitions. Through this study, we contribute to that development by offering conceptual and methodological contributions to transition design discourse. Conceptually, we introduce a framework that connects five key transition design activities with three evaluative qualities of its outcomes: 1) desirability among different actors to ensure uptake, 2) plausibility in contributing to transformative behavioural changes at multiple system levels over time, and 3) networkedness of interventions within a portfolio. Through the development of this framework, we provide support in structuring transition design processes and their intervention evaluation. This is particularly valuable in emerging

fields like transition design, where research and practice are still maturing. By linking transition design activities to outcome qualities, the framework can foster dialogue and collaboration within transdisciplinary teams while establishing a shared language by which to engage external actors. This is crucial for securing support for intervention development, implementation, and scaling.

Methodologically, this study demonstrates how introducing quantitative testing within intervention evaluation can strengthen transition design as a reflexive and evidence-based practice. Our findings suggest that desirability, plausibility, and networkedness are critical for assessing the potential of interventions to drive systemic change. However, the study also highlights that overlooking feasibility and viability may hinder implementation and limit actor commitment. Future research should, therefore, explore how feasibility and viability can be integrated into evaluative frameworks to offer a more comprehensive basis for intervention assessment.

Further work is also needed to support decision-making around portfolio prioritisation, to improve the communication of intervention reasoning across both individual (experiential) and systemic levels, and to refine methodological approaches. In particular, greater attention should be given to how quantitative, qualitative, or mixed methods research can be applied across different phases of transition design, from conceptualisation through to implementation. Advancing these evaluative practices will be essential for building more credible, systemic, and impactful transition design processes capable of addressing complex societal challenges.

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Appendices

Appendices to this article can be found online [here](#).

<https://systemic-design.org/contexts/vol3/v3002/>

About the authors

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Rick Schifferstein is an associate professor at the Faculty of Industrial Design Engineering at Delft University of Technology. His research focuses on (multi)sensory perception, food design, and experience-driven innovation. He has authored over 100 papers in international journals. He is the principal editor of the *International Journal of Food Design* and has co-edited several books, including *Food, People and Society* (2001), *Product Experience* (2008), *From Floating Wheelchairs to Mobile Car Parks* (2011), and *Advanced Design Methods for Successful Innovation* (2013). Rick is the founder and director of the Food & Eating Design Lab, where staff and design students collaborate to enhance people's interactions with food in daily life.

Jotte de Koning is an assistant professor of Design for Sustainability at Delft University of Technology. She is a design scholar and an active member of the transition design and systemic design communities. These communities aim to study and apply design to create value for society. In 2019, she co-founded the Delft Systemic Design Lab and currently serves as its acting director. She works across different transition domains, including the protein transition, food waste transition, energy transition, transition to a circular economy and sustainable healthcare. Jotte has published articles on value dimensions in social innovation; on design principles; on sustainable consumption behaviour; on the concept of co-creation and participatory design; on participatory design and the complexity of sustainability transitions in cities and on food system transitions.

Nynke Tromp holds a PhD and is programme director at the Dutch Design Foundation to develop the public design practice in the Netherlands, commissioned by the Ministry of Education, Culture and Science. She is a co-founder of the Systemic Design Lab, co-founder of Redesigning Psychiatry, and author of *Designing for Society* (2019).