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Could Systemic Design Methods Support Sustainable Design Of Interactive Systems?

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The power of artefacts to reflect our culture and influence us as individuals, as highlighted by *Understanding Material Culture* (Woodward, 2007) shows the importance of design in the ecological transition, a major issue in our society. Although sustainability cannot be based on technological solutions (Bremer et al., 2022), it should be a central concern of human-computer interactive systems design (Blevis, 2007).

In Human-Computer Interaction (HCI) and Systems Engineering (SE), current efforts for a more sustainable world focus on the energy efficiency of a system, optimising its lifecycle and encouraging users to save energy. Some voices in the HCI community recognise that the current approach, which focuses on the material impact of artefacts, is reductive and insufficient in the face of this systemic problem (Knowles et al., 2018). It misses the opportunity to facilitate a necessary change in societal practices. In fact, Sustainable HCI projects attempt to respond to problems that have not been clearly formulated (Rivière, 2021), and the community struggles to develop tools and methods for this purpose.

Systemic design, an emerging practice resulting from the combination of design and systems thinking, has developed methods for addressing complex problems. This paper proposes to draw inspiration from these methods to apprehend the systemic dimension of the ecological transition in the design of interactive systems, particularly in the formulation of the problem and the objectives.

However, these methods and tools are designed by and for ‘systemic designers’. These, unlike interactive system designers, operate primarily at the scale of organisations and social systems (through policy, strategic decisions, etc.) within the framework of design 3.0 and 4.0 as described by Jones & van Patter (2009). This paper argues that the unit of analysis can be decorrelated from the unit of intervention, i.e. one can study and target a problem at the scale of a sociotechnical system (such as the agriculture sector) and only intervene at the scale of an interactive system (e.g. agricultural robot). It is a question of understanding the contexts in which the designed system will be placed and its possible impacts at scale so as to avoid simplistic solutions that could be counterproductive (e.g. rebound effect).

This difference in the scale of the unit of intervention implies that the tools of systemic designers must be adapted to the needs of interactive system designers. The authors suggest the use of 'quali-quantitative' modelling.

KEYWORDS: systemic design, interactive systems, Human-Computer Interaction, systems engineering, sociotechnical system, social system, sustainability, methodology

RSD TOPIC(S): Methods & Methodology, Socioecological Design, Sociotechnical Systems

Introduction

Understanding Material Culture (Woodward, 2007) has highlighted the power of artefacts to reflect our culture and influence us as individuals. This suggests that design has great importance in the ecological transition, the biggest challenge facing our society. Sustainability cannot be based on technological solutions (Bremer et al., 2022), but designers must take responsibility as part of the problem and as a possible part of the solution (Thackara, 2005, p. 12).

In particular, designers of human-computer interactive systems, who aim to address human problems (Mankoff et al., 2007, p. 1) and improve their quality of life (Walden et al., 2015, p. 6), must now place sustainability at the heart of their concerns (Blevis, 2007). The design of human-machine interactive systems (systems whose operation depends on the information provided by an external environment, consisting of one or more human beings) concerns the Human-Computer Interaction (HCI) and Systems Engineering (SE) communities.

Sustainability research efforts in the fields of HCI and SE focus on energy efficiency, life-cycle optimisation and presenting indicators to users to motivate them to save energy. Within the HCI community, several recent papers recognise that the current approach, which focuses on the material impact of artefacts, is reductive and insufficient in the face of this systemic problem (Knowles et al., 2018). This approach remains superficial and does not support a necessary change in societal practices. Indeed, sustainable HCI projects attempt to address problems that have not been clearly formulated (Rivière, 2021), and the community struggles to develop tools and methods for this purpose.

This paper proposes to draw inspiration from systemic design methods to apprehend the complex challenge of sustainability in the design of interactive systems. However, these methods and tools are designed by and for "systemic designers". These, unlike interactive system designers, operate primarily at the scale of organisations and social systems (through policy, strategic decisions, etc.) within the framework of design 3.0 and 4.0 as described by Jones & van Patter (2009). This paper argues that the scale of the socio-technical system can (and should) be taken into account in the design of interactive systems. This implies decorrelating the unit of analysis from the unit of intervention. For example, it may be useful to understand the issues of the agricultural sector (socio-technical system) when designing agricultural robots (interactive systems). By understanding the contexts in which the designed system will be placed, and its possible impacts at scale, one could avoid simplistic solutions that could be counterproductive (e.g. the rebound effect).

Because of this difference in the scale of the unit of intervention, we believe it is necessary to adapt the tools of systemic designers to the needs of interactive system designers. To facilitate the explicit recognition of systemic issues by interactive system designers (without the need to master theories of systems thinking), we suggest the perspective of 'quali-quantitative' modelling. By making the link between systemic design and interactive systems engineering, this paper aims to open a new perspective for HCI and SE communities to understand and address sustainability.

Section 2 begins by positioning the efforts of HCI and SE communities regarding sustainability to highlight the need for a more systemic approach and a methodology to formulate the complex problems of the ecological crisis. It then considers the usual positioning of systemic design within the levels of design as defined by Jones & van Patter (2009). Section 3 goes into more detail in the analysis of methods and tools. We consider the potential and limitations of HCI and SE tools to address systemic issues and discuss the potential and limitations of systemic design tools to support interactive system design. Section 4 opens the perspective of 'quali-quantitative' modelling.

State-of-the-art

Systems engineering and sustainability

Engineering can be defined as "the practice of creating and sustaining services, systems, devices, machines, structures, processes, and products to improve the quality of life" (Walden et al., 2015). Improving quality of life should involve targeting sustainability if the time frame considered includes the future. In fact, engineering should be at the heart of sustainability efforts, given the ubiquity of engineering activities and their role in the economy and in environmental degradation (Rosen, 2012, p. 2270). Systems engineering, which originated in the military sector in the 1930s, takes a holistic view of the system to be designed, as opposed to the reductionist view of engineering specialities. As pointed out by Bakshi & Fiksel (2003), sustainability should be primarily about SE, as it is a property of the overall system (including socio-economy and environment) and not of sub-systems.

Yet, environmental considerations were until recently relatively poorly represented in SE (only one page in the INCOSE handbook, Walden et al., 2015). In engineering and SE, current efforts for a more sustainable world focus mainly on the energy efficiency of a system (reducing the energy needed to perform a task/mission) and the optimisation of its life cycle (choice of materials and design facilitating maintenance, refurbishment, reuse of parts, and recycling).

The improvement of energy efficiency starts from a good intention, but it is symptomatic of the Cornucopian paradigm and provokes a counter-productive phenomenon now unfortunately well known as the "rebound effect" or "Jevons' paradox" (Vezzoli & Manzini, 2008, p. 33). Thus, in parallel with the improved efficiency of car engines, there is a change in behaviour at scale and an overall increase in fuel consumption (Combaz, 2022). The same effect is observed between road capacity and traffic congestion (see Figure 1).

The analysis and optimisation of the life cycle impact of a system is undeniably a more holistic approach, as it addresses not only the direct material impact of use but also that of production, maintenance, and the end of life of the product. Many efforts are directed towards the development of sustainability indicators and their optimisation over the entire life cycle through Multi-Objective Optimisation and Multi-Criteria Decision-Making (Guillén-Gosálbez et al., 2019). Also, a decision-support tool is being developed to determine the best regeneration trajectories (repair, reconditioning, recycling, etc.) based on the health of the system and/or its constituents, as well as cost, environmental impact, and market needs (Vanson et al., 2022).

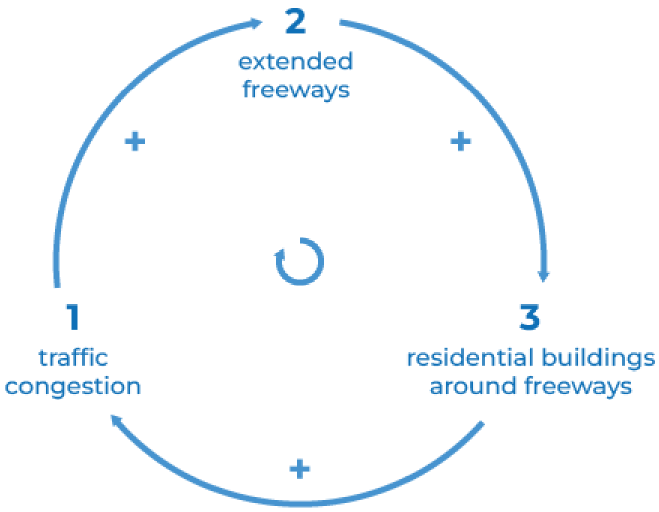

Figure 1. Causal loop diagram of the rebound effect of traffic congestion (Stasinopoulos, 2009).

These efforts are essential, but they are part of a 'business as usual' scenario: isolated, they do not make it possible to support the inevitable shift in societal practices (e.g., in aviation, the only sustainable scenarios include sobriety: Delbecq et al., 2022). They focus essentially on the material impact of a system and not on the use that will be made of this system. One can design a system that is energy efficient and life cycle optimised but whose existence and use are unsustainable: an “environmentally friendly” bulldozer running on hydrogen that it is used to destroy rain forest cannot be classified as sustainable technology. (Misra, 2008, p. 946)

This echoes a common expression in systems engineering: *are we building the system right?* (verification) and *are we building the right system*? (validation). Although SE is closely related to systems thinking, its approach to sustainability is missing a systemic perspective.

Human-Computer Interaction and sustainability

The history of HCI, linked to the introduction of the first computers, is more recent than that of SE (1960s). Three waves of HCI can be distinguished, with an increasingly broad focus: the first sought to reduce the errors of expert users, the second aimed to facilitate tasks for non-specialist users, while the third is interested in everyone and takes into account social and emotional dimensions (Bremer et al., 2022), as represented in Table 1.

Table 1. The three waves of HCI (inspired by Bremer et al., 2022).

First wave	Second wave	Third wave
technical experts	non-specialists	everyone
first computers and systems	minicomputers with graphical user interface (GUI)	mobile phones, web-based tools like blogs and wikis, social networking
focus on users as 'human factors'	focus on users as 'human actors'	focus beyond user-machine interactions
reduce errors and disruptions	facilitate tasks	social and emotional aspects
empiricism and quantitative methodologies	drawing from psychology and cognitive, some qualitative methods	drawing from disciplines like anthropology and sociology, more qualitative methods
objectivist standpoint	objectivist standpoint	social-constructivist and phenomenological approaches

HCI, which has been seeking to respond to human challenges since the second wave, has gradually started to consider the issue of sustainability over the last two decades. Sustainable HCI was initially structured around two axes: 'sustainability in design' and 'sustainability through design' (Mankoff et al., 2007, pp. 2-3). 'Sustainability in design' is comparable to the SE efforts mentioned above: reduction of the energy consumption of terminals and interfaces (fewer requests, page loads, dark mode, etc.) and reduction of the impact of the device life cycle. 'Sustainability through design' consists of influencing user behaviour (persuasive design) towards more sustainable choices, for example, by presenting consumption information ('eco-feedback') to guide daily decisions (heating temperature, washing machine start time, etc.).

The two axes of sustainable HCI have been criticised, especially for their reductive approach ('technological solutionism' in a 'business-as-usual' scenario) and for the absence of debate on the objectives to be achieved (Rivière, 2021). Let's take the example of an email management application. The sustainability in design approach would optimise displaying and loading to save energy, and the sustainability through design approach would show the user consumption indicators. But one can imagine a broader approach, which would question the very use of emails and, if necessary, would make a more sustainable practice easier for the user (e.g. time-limited emails, which are automatically deleted when their content is no longer relevant.). This caricatural example is meant to highlight the fact that, here again, the difficulty lies in formulating the problem and the objectives (which emphasises the earliest design phases).

Some voices of the community quickly grasped the systemic nature of the ecological issue (Nathan & al., 2008). Sustainable Interaction Design (SID) invites us to rethink HCI methods, considering that "unsustainable behaviour is often [...] a problem caused not by bad users but by bad design" (DiSalvo et al., 2010). New voices are claiming, through 'more-than-human design' (Giaccardi & Redström, 2020), the need to broaden the human-centred focus to a wider perspective. However, these new guidelines for HCI sustainability remain claims and intentions without methodologies to make them real (Bremer et al., 2022, p. 6), and the community is still struggling to build a shared vision of the role of HCI in sustainability (Knowles et al., 2018, p. 1).

The need for a systemic perspective and a methodology to formulate complex problems in the sustainable design of interactive systems

In engineering, as in HCI, the issue of sustainability is recognised as unavoidable, but the methods for addressing it are lacking. There is a rejection of the Cornucopian paradigm and an awareness of the complex and systemic dimension of the ecological crisis. Within both communities, some recognise the need to broaden the focus of their approach 'from techno-centric concerns to socio-centric concerns' (Misra, 2008) and beyond interaction (Taylor, 2015), 'beyond user-centric design' (Sevaldson, 2018a).

For the design of interactive systems, it is no longer a question of relying on technological solutions to continue our current lifestyles, but rather of supporting a change in societal practices and embodying this transition in the artefacts, or at least not designing unsustainability: 'design no harm' (Bremer et al., 2022). Intentions must now converge towards concrete methods to address the complexity of sustainability, and these must become mainstream, as suggested by Coskun (2022).

Both SE and HCI communities are struggling to find consensus on the definition and objectives of sustainability, as well as on indicators and evaluation models. The difficulty lies in the ability to formulate the complex problem of sustainability. We believe that it is not necessary to agree on a single, consensual definition or objectives, but it is essential to identify methods and tools to formulate them on a case-by-case basis. This paper proposes to draw inspiration from the methods and tools developed by systemic design, an emerging practice resulting from the combination of design and systems thinking.

The level of intervention in systemic design

Systemic design is an emerging approach that links systems thinking and design to develop « novel perspectives, processes, ideas and even theories » (Sevaldson, 2019) to address complex systemic problems. This growing practice is particularly prolific in terms of methods and tools (from the 1st to the 10th edition, more than 38% of the contributions to the RSD conference are tagged with the topic "methods and methodologies").

However, systemic design mainly addresses societal problems and situations, operating at the level of business strategy or « public policy, urban planning and habitability, food security, equitable economics, community sustainability, ecologically sensitive energy, and healthcare systems » (Jones, 2020, p. 3). Based on Richard Buchanan's (1992) definition of four universal orders of design (1- Artifacts and communications, 2- Products and services, 3- Organizational transformation, 4- Social transformation), Jones

(2020) refers to four levels of design and places systemic design on levels 3.0 and 4.0 (see Figure 2).

In line with the 'products are systemic objects' focus of the RSD11 symposium and with the material culture movement (Woodward, 2007), we believe that systemic issues can and should be considered in the design of products, especially interactive systems. This means extending the unit of analysis beyond the unit of intervention (design 2.0) up to a societal level (design 4.0). The challenge of this difference in scale has been identified by some voices in the SE community.

> The concept of sustainability often requires macroscale consideration of the ecosystem and economy, yet actual decisions are made at finer scales. Therefore, methods are needed for translating the effects of decisions at finer scales upon global sustainability, and, conversely, for interpreting global sustainability goals and indicators to guide detailed decision-making. (Bakshi & Fiksel, 2003, p. 1354)

This paper argues that to take account of systemic issues (such as ecological transition) in the design of interactive systems, we can draw on the methods developed by the systemic design community, but we need to adapt them to the needs of HCI and SE. The following section explores what is missing in HCI and SE methods and tools to integrate a systemic perspective (in the sense of the social system) and what is missing in systemic design methods and tools to be applied to interactive products design (to meet the needs of interactive systems designers).

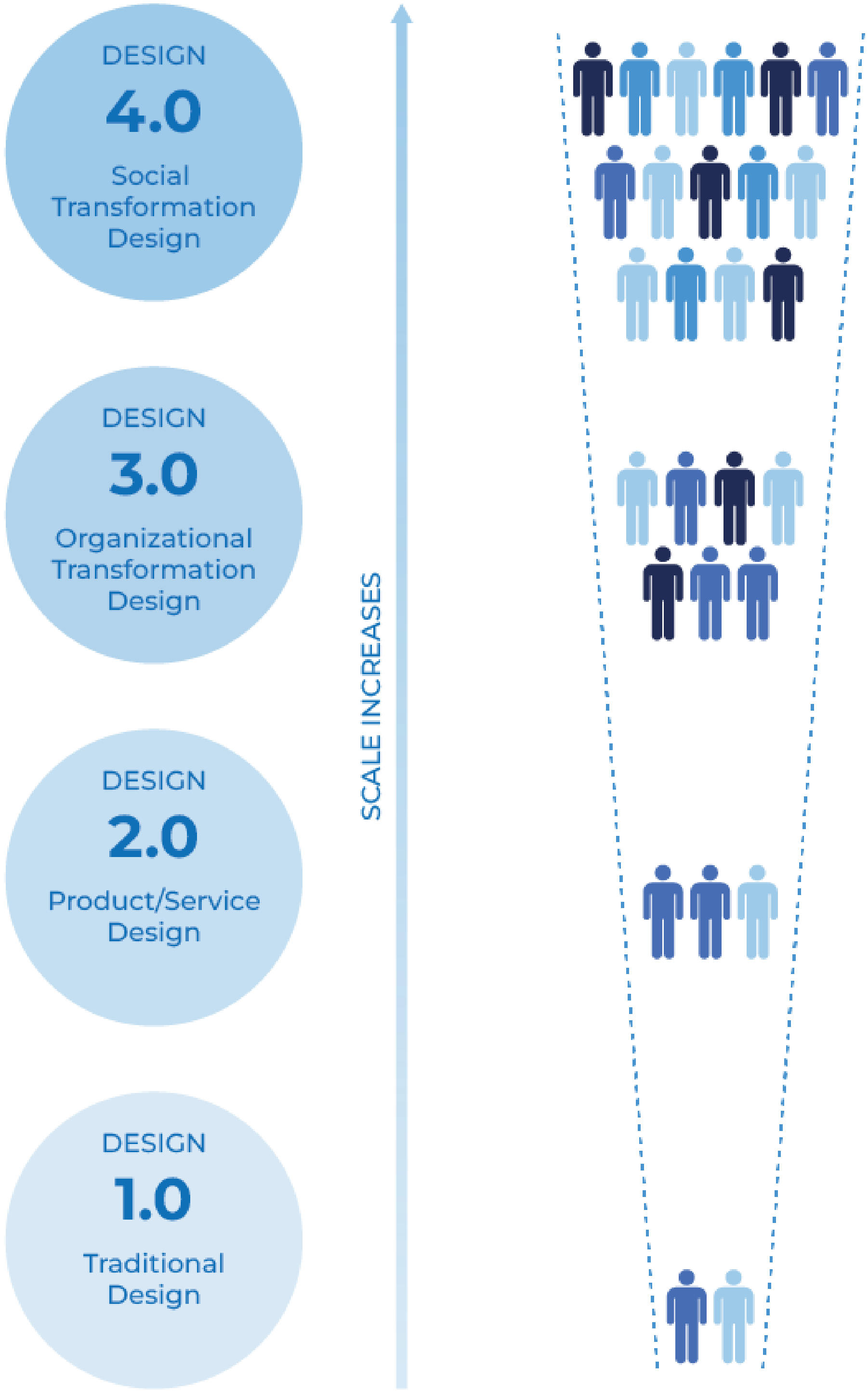

Figure 2. Mapping design process to challenge complexity (Jones, 2013).

Systemic methods and tools to inform the sustainable design of interactive systems

Systemic methods in systems engineering

Systems engineering claims a systemic perspective, as opposed to the reductionism of the Cartesian approach of engineering specialities. Indeed, SE has developed to carry out complex projects with a global, transdisciplinary vision. Jackson (2010) describes systems engineering as part of “hard systems thinking,” one of the five branches of systems thinking (organisations as systems, hard systems thinking, cybernetics, soft systems thinking, and emancipatory systems thinking).

Without going into detail, SE ('hard systems thinking' oriented) focuses its systemic approach on the system to be designed, whereas systemic design ('soft systems thinking' oriented) has a systemic view of the situation and recognises that humans approach the world through subjective mental models (worldviews).

> Systemic design (or systems-oriented design) differs from the common-ly designated systems design in that systemic design is a design field (systemic as the modifier of design) and systems design is the design of systems as objects, a practice developed through systems engineering. (Jones, 2020, p. 1)

The many currents of systems thinking, each built in opposition to the previous ones, have used the same notions for different meanings, which can lead to confusion (see Table 2).

Systems engineering already has methods and tools for dealing with complexity and risk, but these are more suited to quantifiable problems. These transversal methods and tools are based on quantitative and unambiguous models and data (such as numerical indicators and functional requirements). This rigour allows for the continuous verification of the conformity of the system to be designed or for the optimisation of the design, as mentioned in part 2.1. Yet, these data cannot account for human and social aspects, which cannot be reduced to quantitative values. For this reason, the SE community experiences difficulties in integrating the quality of the user experience (satisfaction, fluidity, intuitiveness, etc.) in the formulation of requirements.

Table 2. Different meanings of the typical systems thinking notions (inspired by Jackson, 1991).

notion	hard systems thinking	soft systems thinking
system	the system to be designed	any existing system
socio-technical system	humans and artifacts organised to design, produce and/or operate a system	general description of an organisation of humans and artefacts
complexity	complexity of the solution	complexity of the problem
	aims to master the complexity	aims to appreciate the complexity
emergence	(designed) function/property of the overall system that cannot be attributed to its parts	(observed) emergence in the process of inquiry
model	describes the real world	helps us appreciate the real world
feedback loop	in the system to be designed	in the process of inquiry

Misra (2008) calls for a shift from Techno-centric Concerns to Socio-centric Concerns, but SE tools are not adequate. The human, social, economic and political dimensions are often ignored or left out of the design process, considered as external factors, expressed as initial constraints (e.g. in Rosen, 2012).

> The social question is probably the key issue to solve for stopping rebound effects with the development of technology. It is human behaviour and the resulting social dynamics that lie at the heart of today's social and ecological problems. (Misra, 2008, p. 947)

Human–Systems Integration is an emerging approach in systems engineering that aims to better integrate human and organisational issues into SE (Boy, 2020). The focus on technology is replaced by the Technology-Organizations-People triptych. To this end, Boy (2017) is drawing on Human-Centred Design (HCD) techniques, which are well known within the HCI community, and introduces the notion of socioergonomics (Boy, 2022) to study sociotechnical systems (STS), considered a system of systems. The following section (3.2) indicates that HCD techniques are interesting for our purpose but that the HCD approach is not sufficient to address the ecological transition systemic challenge.

Boy (2017) proposes to involve users in virtual prototypes (virtual HCD), which can represent the sociotechnical system. But this is a sociotechnical system in the sense of systems engineering, i.e., STS to be designed (a work system). It is difficult to imagine an immersive prototype representing a complete social system, but a modelling tool could be appropriate.

> Even if historical knowledge is always useful to anticipate possible future, accurate (mathematical) prediction based on past experience is impossible in the long term. » [...] « Conversely, we can anticipate possible futures and test these claims. » [...] « Modeling and simulation is a good way to assess possible futures. (Boy, 2017, p. 6)

In fact, SE is increasingly relying on modelling to address complexity with the rise of the Model-Based Systems Engineering approach. However, modelling tools are mainly used in systems engineering to represent a system of interest and its functional environment (i.e. a physical system to be designed, but also a sociotechnical system that includes human operators, or more generally, a system of systems). It seems more complex (and unusual) to model the wider social system in which the system of interest is situated.

Ultimately, SE has tools to represent complexity, such as models and quantitative indicators. However, these relate to the system to be designed and require quantitative and unambiguous data, which may be unsuitable for representing the challenges of a social system.

Systemic methods in HCI

HCI, and especially its subfield Computer-Supported Cooperative Work, commonly use Human-Centred Design methods and techniques. HCD's approach is not limited to interaction design or even to the realm of design: it has spread to business and engineering environments, allowing it to get away from the focus on technology and to better consider the needs of human users or customers (Sevaldson, 2018a). In fact, HCI designers, without knowing it, have adopted an approach that could be described as "systemic", close to soft system thinking and complex thinking (Morin, 1992). Indeed, they respond to wicked problems (Rittel, 1973), which evolve during the design process and to which optimal solutions cannot be addressed, but only preferable ones, according to subjective criteria. They reject the positivist paradigm in which theory precedes practice and establish a dialogue with the situation (Schön, 1983). HCD uses concepts and techniques derived from other disciplines, such as ethnography, sociology, and anthropology (Rogers, 2004). The elicitation of users' needs is conducted through field studies, using techniques such as observations and interviews, and the users are involved in co-design workshops.

But according to Sevaldson (2018a), the HCD perspective is by its nature anthropocentric, and this focus on users overshadows the non-users. Therefore, he proposes a de-centric and multi-perspective approach.

> By applying multiple perspectives, we can easily overcome the one-sided view resulting from singular perspectives. This helps us to interpolate different needs, it helps us to uncover unintended and counterintuitive effects from our interventions and it helps finding creative solutions and synergies between diverting needs. (Sevaldson, 2018a, p. 523)

HCD techniques are very similar to those used by systemic designers. One might therefore think that it would be enough to change the focus to allow HCI designers to have a systemic approach. They could consider different scales and interview different people with multiple viewpoints and specialities (for example, in the case of the agricultural sector: farmers, consumers, government representatives, associations, etc.). We believe that HCD techniques can be used for information gathering and for co-designing solutions, but we feel that designers lack the means to synthesise and represent the social or sociotechnical system of interest, as well as the different solutions under consideration. Generally, the results of the user research are synthesised in the form of scenarios and/or mappings. For example, the user journey represents the successive stages of a user's action and the associated positive and negative points. These representations typically focus on the experience of a single user and do not capture the multiple layers of a social system-wide investigation (such as the agriculture sector). Our emphasis here is not on processes (activities and techniques), but on a tangible, manipulable tool for representing systemic issues and accompanying design choices.

Systemic design methods in interactive design

The tools and methods of systemic design have great potential for putting the intentions of Sustainable HCI and Sustainable SE into action. However, despite some breakthroughs in the professional world of digital design, they are still largely unknown to the academic communities of HCI and SE. This can be explained by a relative lack of porosity between these communities (DiSalvo et al., 2010), as well as by the need to adapt these methods and tools to the needs and activities of HCI and SE.

The methods and tools of systemic design are numerous and expanding. As mentioned in section 3.2, the techniques used for information gathering and co-design are comparable to those used in HCD. The focus here is on ways of representing systemic concerns (and identifying leverage points) through the example of four systemic design tools (see Figure 3), from the most abstract to the most concrete.

1. **The systemic design toolkit** (*Systemic Design Toolkit*, n.d.) is a powerful collection of tools which makes explicit the complementarity between the tools adapted from design thinking and systems thinking. The description of the system (Step 3 - Understanding the system), as well as the identification of the leverages, is very abstract and relies heavily on the experience of the systemic designer.
2. **Gigamaps** (Sevaldson, 2018b) are rich representations (whose formalism is completely free) of the different dimensions and dynamics of the situation and can also integrate user experience aspects. This technique, which deliberately refuses to impose a resolved modelling of systems, also requires experience and drawing ability.
3. **Causal loop diagrams** (Kim, 1992) are inherited from system dynamics. They are a more formal (and therefore more constrained) description of the influences and causal loops of the system of interest. Their formalism helps to

guide beginners and to recognise more explicitly the patterns between several situations, as well as the leverage points.

4. **Leverage analysis** (Murphy & Jones, 2020) is based on a formal (and constrained) representation of the system, such as causal loop diagrams. This tool relies on graph theory to identify leverage points and other remarkable points in the graph. The ambition is to provide a decision support tool to guide the designer. However, it must be kept in mind that any model is false and incomplete and that the results of the analysis are only indications that must be challenged.

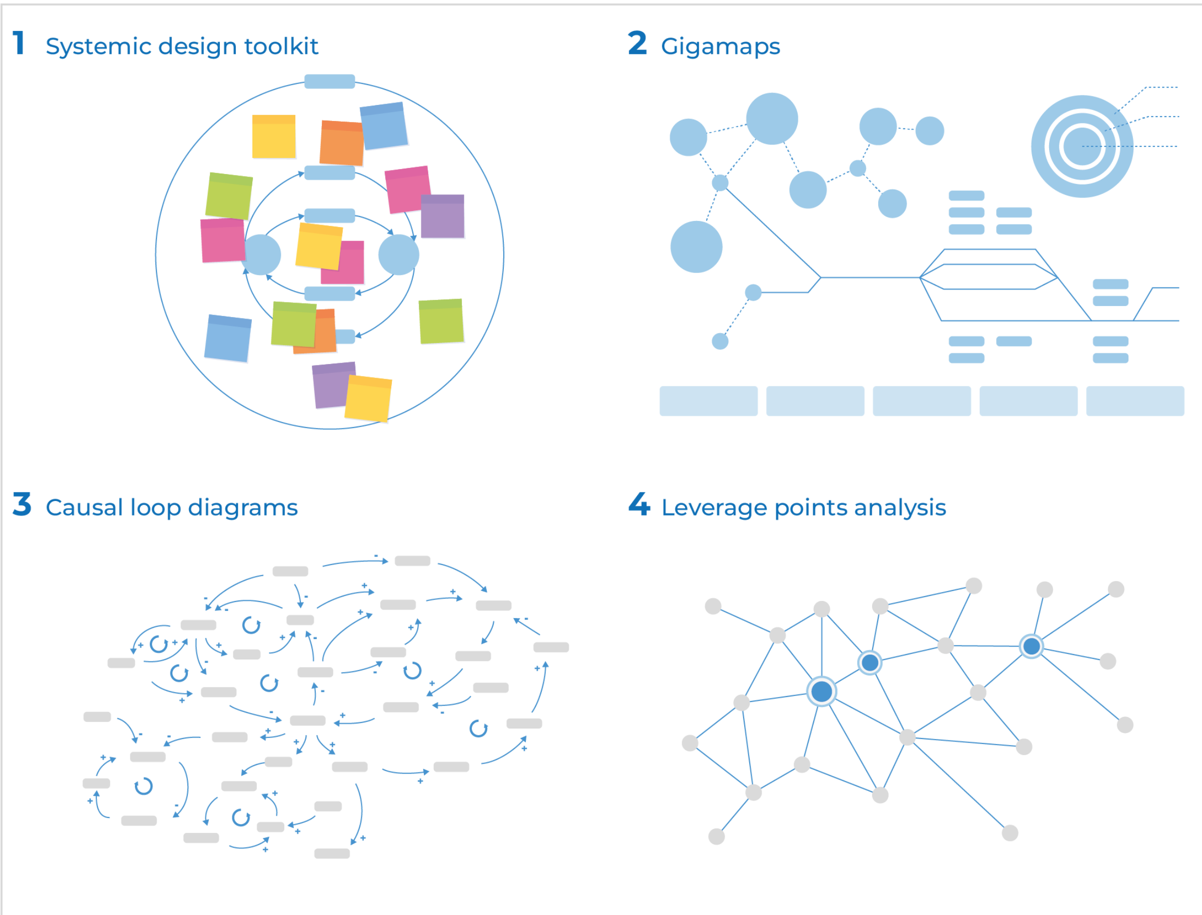

Figure 3. Examples of systemic design tools inspired by: (1) Systemic Design Toolkit. (n.d.), (2) Sevaldson, B. (2018b), (3) Wieck, G. (2021, April 7), (4) Murphy, R. J. A., & Jones, P. H. (2020).

These tools make worldviews explicit and allow for the collaborative construction of a model of the situation, which is assumed to be subjective and inaccurate. However, they are relatively static and more or less adapted to the design of interactive systems and to the diffusion of the systemic approach in the HCI and SE communities. As Rogers (2004) indicated, HCI practitioners only appropriate those concepts, methods, and tools that they can directly apply in their practice without necessarily mastering the underlying theories. In this context, we believe it is preferable to approach them with a certain formalism. Moreover, interactive designers need to dimension the parameters of their systems and test their design on prototypes. Therefore, we think that the first mapping tool for interactive system designers could be between levels 3 and 4 (see Figure 4).

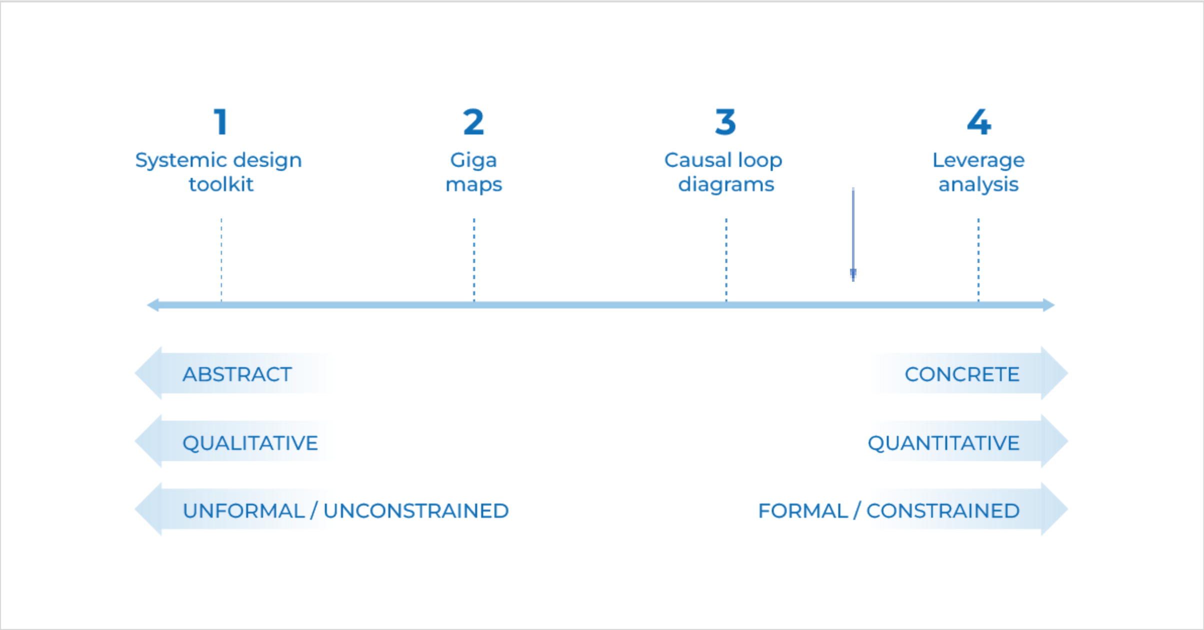

Figure 4: Systemic design tools from abstract to concrete

The perspective of *quali-quantitative* modelling

As mentioned in the previous section, traditional HCI and SE methods and tools do not allow for the representation of systemic issues at the level of social systems. SE considers social issues as input data, starting constraints that should be quantified. The tools of systemic designers allow the construction of representations of these issues, but they are relatively static: they do not facilitate the projection of several scenarios in order to compare possible futures. Moreover, they do not offer guidance, decision support, or the means to dimension the parameters of a product according to a desired future.

As Dennis Meadows points out, humans understand the complexity of the world through mental models (de Rosnay, 1975, page 125). Assuming that any model is a reduction of the world (Korzybski, 1933), it becomes interesting to make these models explicit and to co-design a common model to articulate visions in order to address a complex situation. Dynamic models allow delay representation, simulation and projection of scenarios, but they generally impose a rigorous formalism and quantitative data, which leads their users to reduce or ignore qualitative aspects.

Following Jackson's critical thinking (2010), this paper argues that it is possible to make the most of the different strands of systems thinking, such as soft systems thinking (model co-building) and systems dynamics (simulation of scenarios). We propose *quali-quantitative* modelling, which brings together qualitative and quantitative data, and which focuses mainly on orders of magnitude rather than on details.

> Because design is an applied field, the models used by researchers are often unnecessarily detailed for our use: we care about major effects, not the subtle ones so necessary for the research theorist. (Norman, n.d.)

Quali-quantitative modelling could allow designers to (see Figure 5):

- represent the STS of interest and its dynamics, with a formalism that could be close to causal loop diagrams;
- represent the system to be designed within this STS of interest;
- represent the interactions between the system to be designed and the STS;

- size the relevant elements: orders of magnitude, thresholds, delays, etc.;
- compare several scenarios with different parameters of the system to be designed and different behaviour of the STS.

More extensively, one could imagine the following methodology for designers of interactive systems:

1) Identify the co-design stakeholders and the scope of the STS
2) Build a collective representation of this system (participatory modelling)
3) Understand the dynamics of this system, the possible interactions with the system to be designed, and the risks and opportunities
4) Use scenarios to anticipate possible futures and build a common vision
5) Ideally, identify a spatial and temporal scope for testing their design
6) Keep this modelling up to date with the effects of introducing the interactive system into the STS

Again, the aim is not to make a "digital twin," from which one would draw all the conclusions (the model is false and subjective), but rather manipulate scenarios to better understand the complex and complicated dynamics (many links, large scale, delays). HCI obviously has a role to play in the design of such a tool.

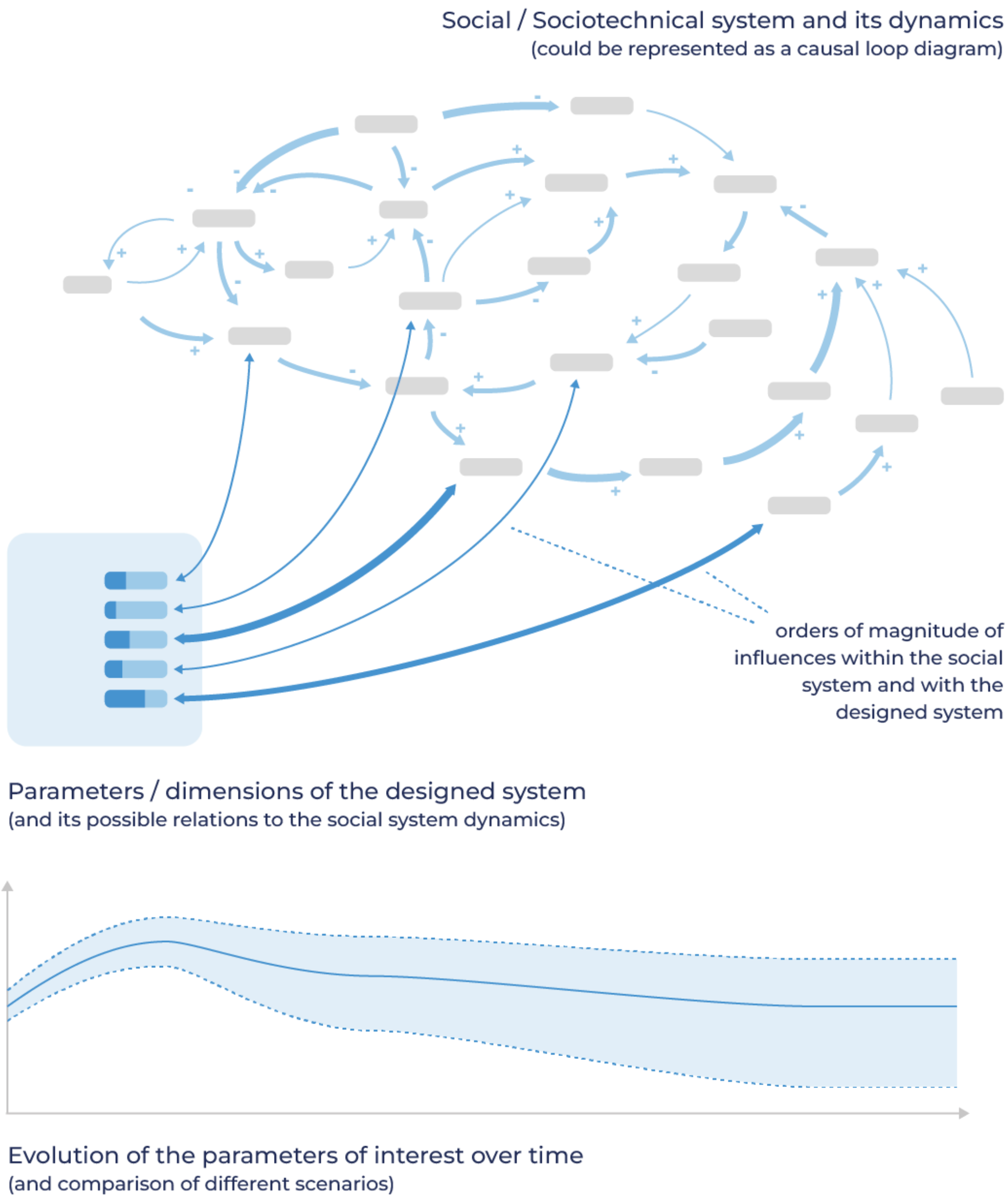

Figure 5. Quali-quantitative modelling—sociotechnical system.

Conclusion

This paper highlighted the difficulty experienced by the HCI and SE communities in addressing the systemic dimension of the ecological transition. In line with the RSD11 focus, Products are systemic objects; we believe that we can aim for (and should anticipate) a systemic impact in the design of interactive systems, i.e. that we can decorrelate the unit of analysis (design 4.0 according to Jones) from the unit of intervention (design 2.0). The methods and tools of systemic design are a source of inspiration but are designed for intervention at the level of an STS or social system. After identifying the limits of HCI and SE tools for mapping systemic aspects and the limits of systemic design tools for combining qualitative and quantitative data, we opened the perspective of 'quali-quantitative' modelling.

It should be noted that the construction of such a tool and the associated methodology (largely inspired by systemic design for the collection of information) will require considerable work. This work could be initiated by using concrete cases of systemic approach in the design of sustainable, interactive systems. Designers, future users and other stakeholders should participate in the co-design of this methodology. We note several points of interest, such as the identification of projects that require such an approach (is there a possible impact at scale?), the definition of the perimeter of the STS or social system, and the way designers and other stakeholders appropriate the tool (ensuring that they keep a critical eye on the co-created model).

Given the time scales of STS and social systems and the uncertainties of the real world, it will be difficult to validate the effectiveness of such a methodology. The only way to see its value will be to analyse several projects over the long term.

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