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Option Evaluation in Multi-disciplinary Strategic Design: Using scenarios for system prototyping

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Evaluating and deciding on technical options is an increasingly complex challenge in disruptive product development and transformative system engineering. The practice requires thinking ahead a path through a regulatory, economic, social and technological unstable environment. Yet, such strategic decisions are often interconnected, dependent on further internal and external variables and need to be communicated and met simultaneously by several disciplines. This holds especially through, when teams from heterogeneous disciplines have to come to consensus on several future events that contain a high level of contingencies. In the foresight research, scenarios are used as alternative prototypes of the future(s) and are the subject of cross-disciplinary discourses and decisions. Based on the analogy between scenarios and prototypes as artefacts of an iterative design practice, we suggest that scenarios can be well applied by designers for knowledge-communication and technical option evaluation among heterogeneous disciplines and stakeholders. With the example of two ongoing transdisciplinary projects (E4A[1], SE²A [2]) a generic 10-step procedure is proposed which can be adopted to similar strategic design inquires.

Keywords: Strategic Design, Decision Making, Option Evaluation, Prototyping, Scenario Technique, Transdisciplinarity

Introduction – Human-System-Interaction in a future system

Which technical option is more sustainable? Equipping the agricultural machine with battery on board, or connecting it with cable to a power station? Which option will gain more acceptance by agricultural socio-economic systems? This and many similar questions are complex and cannot be treated by one single discipline.

Technical decision-making is an increasingly complex challenge in disruptive product development and transformative system engineering. The practice requires thinking ahead a path through a regulatory, economic, social and technological unstable environment. Yet, such strategic decisions are often interconnected, dependent on further internal and external variables and need to be communicated and met simultaneously by several disciplines. This holds especially through, when teams from heterogeneous disciplines have to come to consensus on several future events that contain a high level of contingencies: Will political measures be facilitative or restrictive? How might sociotechnical trends evolve? Could they make our venture obsolete?

A critical requirement for processing such project ventures is a near-realistic prediction on the Human System Interaction (HSI) in the targeted usage time, i.e. anticipating whether the to-be-designed disruptive system is going to meet wishes, needs and consumption patterns of users of future.

The issue has been observed in systems transformations requiring a very long strategic preparation (e.g. electrification of agriculture). The same concern is also valid for designing products with a long life cycle (e.g. civil aircraft design) or in entrepreneurship when pioneering a service for the first time (e.g. Netflix). In all these cases,

[1] Energy-4-Agri: Funded by the Federal Ministry for Economic Affairs and Energy; Project sponsor Jülich, research center Project website: https://www.tu-braunschweig.de/energy-4-agri

[2] Sustainable and Energy-Efficient Aviation: Funded by the German Research Foundation DFG through the Cluster of Excellence SE²A - EXC 2163, project website https://www.tu-braunschweig.de/en/se2a

the socio-technical contingencies inherent in the system exceeds the available certain information, and therefore multi-disciplinary teams are likely to fail in designing a sound solution that is sustainably optimized and meets user needs.

Various approaches have been introduced by the body of systemic design for tackling system complexity (see e.g. Aaltonen, 2010; Jones, 2014), in a few modelling and prototyping play a central role and are the mean of communication through stakeholders (see e.g.Blomkvist, 2014). On the base of the definition for scientific models (Stachowiak 1983), we raise the question, whether we can replace the practice of building prototypes with building scenarios for communicating HSI in future systems.

Scientific Models vs Prototypes vs Scenarios

While scenarios demonstrate many epistemological similarities in form and their functionality to prototypes, less design processes have emphasized on the modelling advantages of scenario technique in facilitating transdisciplinary product development.

Indeed the application of prototypes and other scientific models must be traced back to pragmatism in design practice: they facilitate communication among stakeholders (Kac 1969 in Weinberg 1975:43). Based on design objectives and communicative requirements, prototypes are generated to encode, decode and translate knowledge among stakeholders (Lauff et al. 2020). Near this communicative role that is common among all scientific models, prototypes in design research play also a generative role in enabling the designer to reflect on own design and explore the solution space (Lim, Stolterman, and Tenenberg 2008). On this rational ground, certain prototyping methods (tangible/virtual, low/high fidelity, 2D/3D etc.) has been appealing to particular design disciplines and are even vastly recognized as standard procedure in the design process (e.g wireframing in UX Design).

With design practice emerging in the last years from a traditional creative/innovative role to a rather moderator/mediator role, we believe that scenarios and scenario-technique will increasingly draw more attention as a complementary or even stand-alone modelling and prototyping method in many design sub-disciplines.

Yet, one might raise the question, to what disciplines and how might scenario technique come handy? In his seminal work on model theory, (Stachowiak 1983, 119) allocates three pragmatic functions to scientific models: graphic, technical and semantic functions, noting that a modelling technique might contain more than one pragmatic function. Bearing in mind that scenarios carry essentially all the three characteristics with the main focus being on semantic/ narrative functions (Börjeson et al. 2006; De Smedt, Borch, and Fuller 2013), we suggest that scenario technique will be rather in disciplines advantageous, that are of a disruptive future-oriented nature. Such characteristics are often seen in strategic and service design inquires. In particular, for design commissions, in which, convergence and common perception regarding the problem/solution space is a requirement for decision-making.

User centricity without users

Prototyping is an important phase of an iterative Design process. Iterative low and high fidelity prototypes and usability testing sessions with potential users promise a sound understanding of customer actual needs, wishes and probable incentives for using the targeted product or service. Yet, how to perform the user research in a strategic design approach, when the user is not accessible and/or has no prediction on his long term needs?

From a methodological point of view, we will encounter in such research cases two obstacles:

1- Providing the user with a valid prototype and its future environment for examining the usability is due to technical limitations barely possible.

2-“The user of future” does not exist yet, common marketing-driven surveys and similar measures on current customers cannot validate the desirability of our solution, as "the users of today" do not entirely represent the mindset and other socio-cultural characteristics of their next generation.

In the foresight research, where researchers often deal with various stakeholders with a large set of uncertainties, scenario technique is used to fill the knowledge-gap with the help of so called “consistency analysis” and “plausibility checks” (Ritchey 1998, 2011). Scenarios discuss the probabilities and not the facts (Huss 1988); they have no claim on delivering true knowledge about the future (Kosow and Gaßner 2008). They rather facilitate innovation via trans-disciplinary discussion and mutual creative impulses. Yet, how to integrate (a preferably iterative) user research in a process of generating scenarios? Moreover, which user research methods are best compatible with the scenario process?

Mozuni and Jonas (2018) proposed the approach “Morphological Delphi”, in which tools from foresight research are integrated in design-Thinking method, so that scenarios are generated systematically with the help of experts’ consensus knowledge. Building on this ground, we have designate for our agriculture project a step-by-step approach, in which, not only experts opinion, but user data from various sources (e.g. mass surveying, interviewing, etc.) could be iteratively communicated through scenarios and serve technical decision makings.

Asking experts instead of users

A methodological concern on solutions for the middle and far future is the incapability of the user to depict their future needs. We encountered the same problem in the E4A project regarding the capability of agriculturalists in reflection on the future. Although a qualitative user research (e.g. focus groups) would be in this matter more effective than a quantitative research (e.g. surveying), yet general market research or raising data by surveying current user, might mislead us: many supposed wishes and/or future needs might become obsolete in the long term. The reason is that for the user, unknown data and ambiguous information about the future exceeds the known intelligible knowledge.

Reasonably, in such a case, when common user experience research (UXR) methods are unable to deliver data about “the user of future”, experts opinions are a proper alternative for collecting data (Everett 1993; Sackman 1975). Experts can relate political, economic, technical and social factors and deliver innovative scenarios. Scenarios can then be taken as prototypes and being used in the form of common UX researches.

Scenarios as prototypes for UX researches

As Mogensen (1994) states, prototypes are representations of otherwise internal or unavailable ideas of what the future should or could look like. Seemingly are prototypes seen by Blomkvist (2014) as surrogate for the future situation of service. This definition conveys the same understanding in the body of foresight research about scenarios (see e.g. Börjeson et al., 2006; Fink & Schlake, n.d.; Malhotra et al., 2014).

Therefore, in addition to the functionality of facilitating discourses among experts, scenarios can be effectively used as service prototypes to be used in user experience research approach (UXR), for instance as *service walkthrough* (Figure 1).

Prototyping services are different from prototyping physical products, as they need to consider the whole human system interaction rather than focusing on micro functions. Nevertheless, many designers accustomed and still use traditional UXR approaches, that are tailored for micro (digital) solutions (Blomkvist and Bode 2012). With the help of *the designated Scenario Technique,* UX researches will be able to generate scenarios, visualize them as *Service Walkthroughs* and finally evaluate them with their conventional UXR methods.

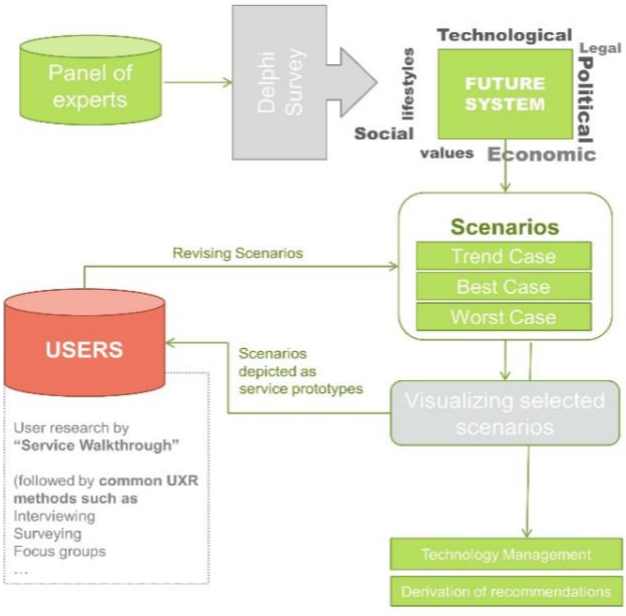

Figure 1: Integrating scenario prototyping and UX research in a strategic design inquiry

Transferring knowledge

Even though transdisciplinary research always aims to combine disciplinary knowledge (inclusive) and tackle problems in a holistic way (integrative) (Carceller-Maicas 2015, 307), we must however recognize that we will never achieve absolute knowledge (Clayton and Ratcliffe 1996, 212; Skrimizea, Haniotou, and Parra 2019, 129). Therefore, elaboration and description of possible futures are nothing than deductive models. Models (i.e. also other methods and techniques) are deductive by definition. Loss of information must be accepted in order to achieve simplicity, clarity and understanding of the research subject (Clayton & Radcliffe: 1996, 190) "We cannot deal with reality in all its complexity"(Cilliers 2008, 50 ff). In this regard, scenarios have the advantage that, in principle, they are simple in nature and convey less details (Kosow and Gaßner 2008; Kosow and León 2015, 219) since they must represent many alternative futures (Braun, A., Glauner, and Zweck 2005). In addition, scenarios have an iterative and thus an adaptive character: Through the constant involvement of experts and stakeholders, the research field must be constantly evaluated and negotiated. In addition, depending on the research field, different methods for stakeholder involvement can be used under the umbrella of scenario technique.

The potential of multidisciplinary or transdisciplinary scenarios lies in conveying information and shared knowledge and facilitating social discourse (Greeuw Marjolein et al. 2000). Thus, scenarios can also be seen as a better alternative to the classic research report to disseminate information (Glatzel and Wiehle 2019). By integrating various actors, knowledge and perspectives, the scenarios also bring a balance of interests between possible stakeholders. It also fosters acceptance and understanding about the generated solution or concept.

Scenarios in the E4A project focus on two narratives: firstly, several possible system states are outlined (target knowledge), secondly, alternatives are discussed, what must happen from today's point of view (or should not happen) in order to achieve a certain system state (transformation knowledge). Both narratives build on improving the systemic knowledge. The complexity of the problem is dealt with participation, creativity and prototyping, in particular by combining several scenario processes. “Scenarios make possible futures tangible” here also means making complexity tangible. Stories have the potential to create understanding for a complex field of research, but it is important to constantly question the truth behind the stories (Sandercock 2010).

Practical implementation in two research projects

With the help of our ongoing projects E4A and SE²A, we outline our designation for using scenarios as prototypes for multi-disciplinary decision-making

The project is characterized with following features:

- Addressing a future system.
- Need for derivation of future digital and analogue products.
- Transdisciplinary Technology management is an issue.
- HSI management with user-centrism.
- Recommendations must be generated for policy making.

For a better understanding of the reasons behind single steps, we follow an inverted goal-oriented requirement chronology (Van Lamsweerde 2001):

Goal a: Recommendations must be generated for policy making

Goal b: HSI must be optimized

Requirement: User must have been evaluating the solutions in advance

Goal: Evaluating solutions by user

Requirement: UX research by Service Walkthroughs

Goal: Providing and running Service Walkthroughs

Requirement: Scenarios must be visualized (for example via VR prototyping)

Goal: Generating scenarios

Requirement a: Morphological analysis must be ran(Álvarez and Ritchey 2015)

Requirement b: trans-disciplinary Delphi workshops must be held

Goal a: Running Morphological analysis

Goal b: relating quantitative and qualitative knowledge from different PEST disciplines

Requirement: Crass-impact analysis & consistency analysis (Mozuni & Jonas, 2018b)

Goal: Crass-impact analysis (see also Ohlhoff et.al 2021)

Requirement a: Building a matrix consisting of factors in columns and their possible projections in rows: Listing macro-worlds (up to 4) as projections of one column named *Macro Worlds*, and several PEST micro factors (up to 9) each with up to 4 projections in further columns

Goal: Building macro-worlds

Requirement: Building 3 or 4 macro scenarios (worlds) with the help of Quattro-stagioni scenario technique(Godet 2006, 82)

Goal : Building 3 Worlds with Quattro-stagioni technique

Requirement: Sensitivity Analysis (Vester 2002)

Goal: running Sensitivity Analysis

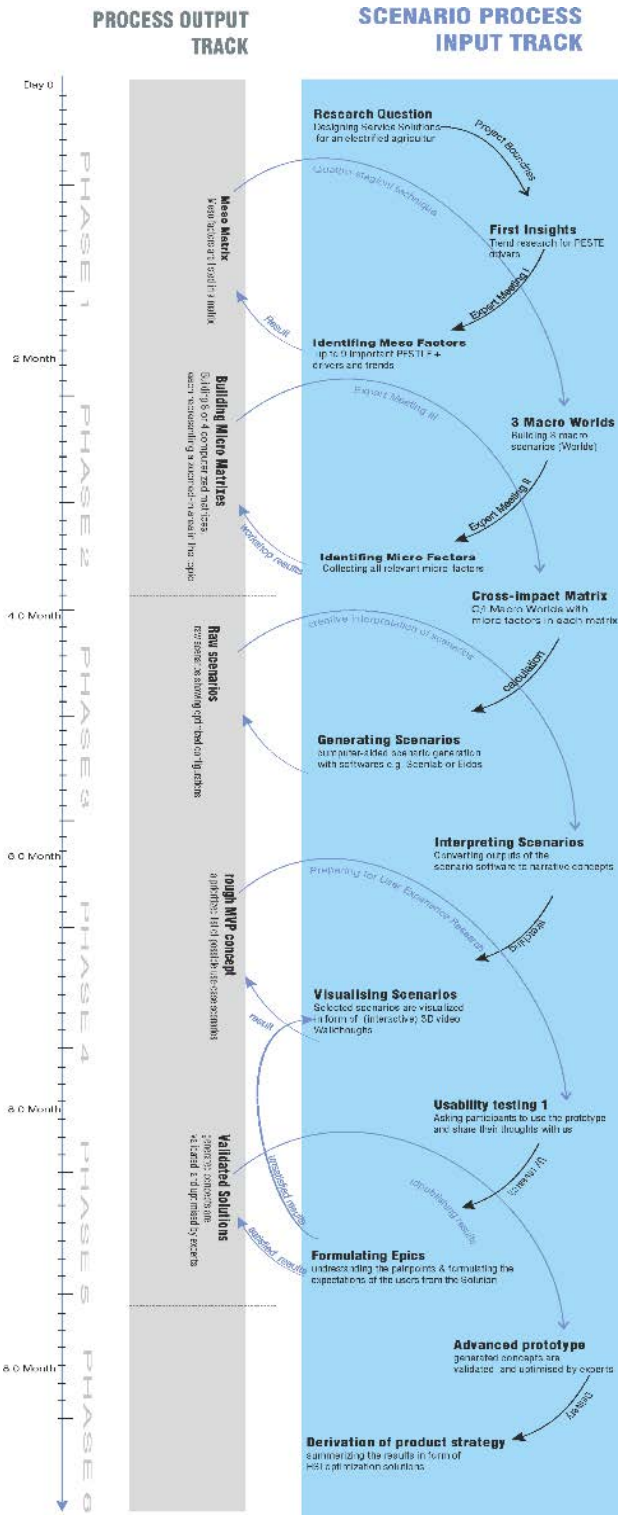

Figure 2: Proposed 10 step designation for trans-disciplinary desicion-making based on scenario tehcnique

Requirement a: running –cross-disciplinary Delphi workshops for identifying 2 most active factors

Goal: cross-disciplinary Delphi workshops

Requirement a: collecting quantitative and qualitative knowledge from different PEST disciplines

Requirement b: research and agreement on the number, phrasing and description of system key-factors (up to 10) and their possible projections (up to 4)

It is possible and is recommended to follow this process in an iterative routine. The process would suit an agile process flow in commercial project managements. Figure 2 illustrates a generic iteration for the 10 steps described above from defining the research question and gaining first insights down to delivering roadmaps and publishing results in a hypothetical 12-month project timing. Rationally, the phases and steps could be adjusted by individual needs based on the timing and the characteristic of the research project.

In the process above, several techniques are barrowed from the foresight research to help us with certain project Goals ending to HIS prototyping for multi-disciplinary decision making. Morphological analysis (Ritchey 2011) works in this approach as the holder on information which is collected via different sources. The cross-functionality between different tools and methods is listed in the table 1.

Table 1: application of forecasting methods in multi-disciplinary option evaluation using scenario prototyping

Project Goals ↓	(qual.)Scenario Technique	Delphi Method/Expert surveys	Morphological Analysis	Scenario visualization / Sc. Walkthrough
Anticipating the future	++	++		
generation of novel solutions	+	+	+	
HIS prototyping	+		++	
Usability & acceptance testing		+	+	++
accelerating collaborative work (Ritchey 2011a)		+		++

Conclusion

Strategic and service design inquiries increasingly have to deal with complex Human-System-Interactions, in which trans-disciplinary agreements on various socio-technical option has to be made. Stakeholder management including prototyping in such cases is essential to generate sound consensus. Within the duality of best practice and efficient practice in this regard, we raise the question whether scenarios and scenario-techniques might be a promising alternative. Qualitative scenarios are epistemologically dynamic story-telling that can ease transdisciplinary discourse about how a desired state might seem. Quantitative scenario approaches enable a systematic matrix-based exploration of the solution space so that no option remains out of sight. On this ground, we encourage designers to consider a mixed qualitative/quantitative scenario technique (such as "*Morphological Delphi*" or "*Morphological Analysis*") as a framework for convergence and reflection in design practice. In practice, one might see also scenarios as an adequate complementary to conventional rapid prototyping approaches for user experience research.

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