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Incertitudes in Design Decisions – Impediments or Instruments?

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Abstract
In product development, reasoning based on information content progressively complements sheer process driven approaches. Here, the coherent set of design decisions is seen as the backbone that enables the design team to initiate, substantiate and assess the evolvement of development trajectories against the context and the requirement specification. Habitually, design decisions are seen as means to reduce uncertainty in development cycles, while implicitly disavowing or ignoring the elusivenesses of the decisions themselves. A different approach is taken here, by making the role of uncertainty, ambiguity, volatility and indeterminism in decision making explicit, both as concerns the underlying information and the process itself. For now, this does not yet overthrow the way in which products are developed, but it does substantiate an understanding of decision accuracy, reliability and sensitivity. With this, product developers are challenged to explicitly address decisions by purposefully employing knowledge on the incertitudes inherent to product development.

Keywords
Design method, decision making, uncertainty

1 INTRODUCTION

Decision making has both expected and unexpected impacts. Even a straightforward, simple choice may lead to unforeseen consequences, with a snowball effect as extreme. Next to such aftereffects, the elusiveness of decision making in itself will also affect its predictability. Oftentimes, designers are not aware of this elusiveness, or lack substantiated means of incorporating it in decision making. Therefore, their only option is to ignore it all together by entirely focusing on the information that is explicitly available. As a result, this information might be mistakenly perceived as correct, certain and unfaltering. This situation does not adhere to lifelike decision making processes, moreover, it results in situations where decision processes convert potentially unreliable information in outcomes that are presented as sound. Obviously, this brings a false sense of exactitude to evolving product definitions and development cycles.

In doing justice to the role and importance of elusiveness in decision making, incertitudes have to be seen as instruments rather than as impediments. To establishing this, the information that underlies decision making should be the pivot of development cycles. However, as design cycles are often seen as being process oriented [1], the information content is often hardly more than a cluttered, complex and potentially oversized collection of useful, but also contradictory, shattered and partially irrelevant information. Especially in the early phases of the development cycle there is a considerable risk that the connection between the design process and the information content is lost, causing disproportional problems in downstream processes. However, the risk of losing this connection is certainly not reserved for the start of development cycles.

2 IS ONLY THE FRONT-END FUZZY?

Product developers excel in generating clear-cut product definitions from ideas, concepts, promises and gut feeling. It is the creativity and workmanship of the designers that allows them to cope with the vagueness and indefiniteness that characterise those development cycles – especially in the earlier stages. From a managerial perspective, however, it is far more difficult to value the elusiveness of development cycles. In an attempt to make the design process seizable, it is often subdivided in three sections [2]:

- fuzzy front end (FFE)
- new product development (NPD) process
- commercialization

In this context, the fuzzy front end is often referred to as the set of activities that come before the formal and well-structured NPD process [3]. With this, the 'chaotic, unpredictable, and unstructured' activities are separated from the NPD processes, which are assumed to be 'typically structured', with an assumed formalism relating to a prescribed set of activities and questions to be answered [2,4].

Interestingly enough, this managerial divide between the fuzzy front end and the 'actual' new product development clashes with the typical designer's perspective. After all, designers purposefully try to integrate downstream aspects

(costs, feasibility, manufacturability, packaging …) in early ponderings and decision making – expressly disclaiming this divide. Moreover, from a design perspective, the projected tangibility and predictability of the new product development process is not necessarily a reality – to say the very least.

In other words, where the managerial (meta-) perspective might indeed be capable of separating the 'unassignable processes' in the fuzzy front end from the 'assignable processes' in the new product development, the design perspective has its focus on the purport of the processes – being comparably uncertain in both cases.

If this design perspective is taken to extremes, the imposed phasing in development cycles cannot be leading. Rather, the development cycle emerges as a set of processes that conjointly and dependently contribute to the advancing knowledge and control of the product under consideration. The processes might adhere to a presupposed phasing but might as well follow a completely different route. Moreover, the processes are no fixed procedures, nor is their sequential execution self-evident. It is not the activity or phasing that defines the metre of development cycles, but the aim of the activity; the expected added value for the new product under development.

Starting from a situation with (usually) a shortage of complete, decisive and reliable information, the development cycle (with all its explorations, iterations endeavours and reconsiderations) constructs a definition of the product that aims to be clear, unambiguous and complete. Simultaneously, the requirements specification is observed, while also adapting and repleting it [1] in the context of e.g. the company's product strategy, improved understanding of the problems at hand or added consumer insights.

In such an endeavour, certainly some anchor points can be helpful to constrain the process, but these have a mostly managerial meaning. The recognition of the fuzzy front end as a phase is merely one of such anchor points. Although potentially these phases are powerful mechanisms to control projects, they should not be confused for a blueprint for actually executing a development cycle.

At the same time, from an overall perspective, the start of a development cycle indeed seems more precarious than the later stages. However, this may be caused by the fact that many stakeholders (implicitly) tend to assess the amount of uncertainty as a ratio against the amount of information already established. Obviously, if hardly any information is available, small indistinctnesses can drive this ratio to extremes. In the later stages of product development, when the product definition is much more elaborate, the relative impact of indistinctness on this ratio may appear much smaller. However, while building the product definition, every next step has a certain (absolute) amount of uncertainty involved. Interestingly enough, this amount is well-nigh independent on the magnitude of the set of all the future decisions looming. This is caused by the reflection that the vast majority of these decisions cannot yet carry meaning for or cannot yet influence the next design step. So, although the future impact of decisions in the earlier stages of product development may be more far-reaching, the actual amount of indistinctness that designers have to deal with does hardly change over the development cycle. In other words, for designers, every next step has fuzzy aspects of its own.

With this, a development cycle is a venture that has a rolling horizon, in which every step attempts to produce an evolvement of the product definition, by assimilating the information, context and indistinctnesses that characterise the current state of affairs. Therefore, the fuzzy front end is not just the starting point of a development cycle. It rather is the ever-fuzzy next step that builds on the already consolidated product definition.

3 DECISION MAKING AS VALUE ADDING ACTIVITY

In the ever-fuzzy evolvement of the product definition, designers continuously aim to translate abstract requirements into well-defined solutions. Designers are particularly skilled in dealing with the uncertainty, ambiguousness and unpredictability that characterizes the development cycle. It is the problem solving focus, creativity and the ability to make decisions under uncertainty that allows a designer to create new ideas and materialise the pursued added value [5]. In this, decision making is the activity that determines the preferred course of action. Simultaneously, there is an important aspect of consolidation in decision making; determining which available option is currently best and which alternatives are abandoned. Consequently, decision making can be understood as a design activity that fosters and consolidates both the product definition and the design rationale.

As such, there is a clear relation between decision making and the information content in a development cycle. Even more, if designing is understood in terms of creating (new) information content [6], rather than a predefined course of actions, then decision making is the elementary activity in establishing that information content. Consequently, the coherent set of design decisions is seen as the backbone or scaffolding that enables a design team to initiate, substantiate and assess the evolvement of development trajectories against the context and requirement specification. Decision making should therefore be understood as a value adding activity.

As there is no conclusive, universal approach for decision making, this paper uses a generic model

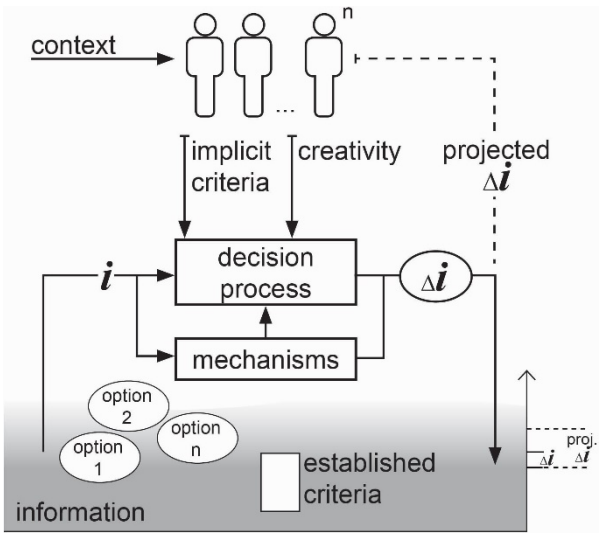

Figure 1 - Decision making explained in terms of information transformation

(figure 1) that addresses decision making as an activity that converts a given input in a certain output, by using mechanisms while adhering to control that is exerted. Although this model assumes that the decision is an activity, it actually emphasises decision making as a transformation of the information content. This implies that decision making leads to an enrichment or fortification of the information content – even if the design team decides to mercilessly kill a concept.

Obviously, not everything in a development cycle is available as concrete, tangible and readable information. Tacit knowledge and implicit decision criteria reside in the assessors of that information: actors. As the main resource of the decision process, actors not only bring (in)tangible control factors into a decision process, actors also introduce creativity. This implies that actors in a decision process act as a kind of referee while simultaneously participating in the game. The complexity of this role is emphasised by the fact that actors are subjective to contextual factors influencing decision processes. Moreover, actors usually have an expectation about the outcome, indicated by the projected delta-information (Δi). In other words, efforts required to establish the information content are not necessarily predictable, straightforward, or unequivocal.

To better understand decision making processes, a distinction is made between explicit and communicable information (like models, facts, data, images, text, correspondence or software) versus implicit information that knowingly or unknowingly is embayed by the actor(s) involved. Both information sources provide the prerequisites (goals, alternatives and projected consequences) for a decision to be made, although there is a clear distinction. The explicit information, various options and previously established decision criteria, represent the deterministic fraction of the design process. Accordingly, tacit aspects such as implicit decision criteria, contexts and creativity denote the indeterministic nature of decisions. By combining both fractions, the inevitable discrepancies between the prospected outcome (i.e. the projected Δi) and the actually established change in information (i.e. the actualised Δi) is made visible. In information-based decision support, such discrepancies often emanate from the indefiniteness of development cycles. With this, it is essential to take into account the uncertainties, ambiguousness and volatility inherent to any decision making process – exactly to improve that process.

4 ELUSIVENESS OF DECISION MAKING

This section describes the elusiveness of decision making in terms of volatility, uncertainty, complexity and ambiguity. The acronym 'VUCA', describes the dynamics and indefiniteness of realistic situations while serving as a framework for strategic decision making [7]. Both the inherent appreciation of lifelike decision processes and the focus on the indefinite aspects thereof makes VUCA an appropriate backbone for describing the elusiveness of decision making in product design.

Given the role of information content in decision making, it is essential that VUCA-aspects are not only related to decision making processes, but also to the underlying information. With this, the decision model itself can be more adequately aligned with incertitudes of the information content, doing more justice to the practical conditions in decision making.

4.1 Volatility

Volatility addresses the nature of change. A volatile situation is subject to change, in which timing and the magnitude of events are not necessarily related to the significance of the impact. Oftentimes, a situation is labelled volatile in hindsight, making it a qualitative measure for the instability of a process or situation.

In the decision model of figure 1, the basis of the volatility of a process is represented by the context in the upper left corner. It characterises the change of contextual factors that influence the actors involved. The causes for a volatile situation in a design cycle generally stem from instability. An example is the unanticipated launch of a competitor's product, thus altering the stated purpose of the current project. Volatility can also be seen as a characterisation of inexplicable actor behaviour. Here, the cause of that behaviour stems from a context different than the development environment of the current project.

By means of e.g. risk assessments, volatility of processes can be characterised. However, the step to controlling volatility of processes is well-nigh impossible. For the information content, however, volatility can more adequately be addressed. Here, volatility has everything to do with validity. Even highly volatile information, such as prices for raw

material, can be encapsulated by explicitly addressing the validity of information.

4.2 Uncertainty

Habitually, design decisions are regarded as a means to limit or reduce uncertainty. Uncertainty is typically regarded as one of the main causes of hesitation and instability in design cycles. While these adverse effects are undeniable, uncertainty also has a more efficacious influence, as it creates design freedom and enables designers to explore new ideas and create new value. In other words, the absence of uncertainty in a design cycle would disclaim the need for the creation of new products.

When expressed or put into estimates, uncertainty conveys the assessment of the unknown but necessary parts of a development cycle. However, uncertainty is not an allocable, delimited area in a decision process. It is so intertwined with the essence of design that it is in fact ubiquitous. Indefinite product definitions, hesitation about previously established criteria or the unsettled future course of actions: uncertainty is literally present in every aspect of decision making. When expressed in terms of the decision model: literally every arrow and delineation is vague rather than fixed. While this may seem to be an unworkable assumption, it does justice to the reality of decision making in design.

In an attempt to purposefully take into account uncertainty in decision making, a practical divide is proposed between ingrained, uncontrollable uncertainty and uncertainty that is considered to be manageable. The latter is regarded as the probability that a designer can, with some effort, be a little more certain about something.

Although commonly regarded as an inherent part of design, uncertainty is not explicitly reflected in the information that is used during decision making. The available information, especially in digital form, seems to claim a certainty that is not congruent with the uncertain nature of design. Additionally, many decisions are not solely based on explicit information, but are supported by heuristics or gut-feeling [8]. Subsequently, the outcome of decisions is often documented as univocal and objectively valid, if documented at all. This renders a sense of certainty that is not justifiable.

Explicit, exchangeable information and implicit, tacit knowledge used in decision making are mutually dependent, the information employed should therefore also bear the signs of the uncertainty that was or is at play. Information in design should therefore not only represent one, explicit message or value but simultaneously convey the value-range of the information. As such it can not only convey the content but needs to simultaneously address the sensitivity of that information.

4.3 Complexity

Complexity addresses the intricate, entangled systems and situations inherent to design. A complex situation or system consists of many interrelated parts, where the relations between those parts can be unclear or unknown. Moreover, such relations can also bear relevance for other products or projects. To mention just one example of complexity, what starts as a singular stakeholder can appear to be a cohesive network of multiple actors. This punctualisation effect [9] postulates that each entity might be a network of different entities when the context or the environment changes. Consequently, it is impossible (and meaningless) to aim for a univocal consideration of the complexity of a system or a situation.

Moreover, in adding value, designers constantly create new artefacts; in other words, they are used to addressing the undefined while attempting to simultaneously addressing relations between undefined aspects. Complexity is considered to be a rudimentary yet fairly uncontrollable aspect of design. With this, addressing volatility, uncertainty and ambiguity seems an appropriate way to limit the effects of complexity on the consistency of a product definition.

4.4 Ambiguity

Whereas uncertainty is depicted by a range of known and (yet) unknown possibilities, ambiguity characterises situations in which the uncertainties are not knowable [10]. Distinctive ambiguities are predominantly found in the earlier phases of product development, when possible routes are considered and the denotation and impact of processes and entities are unknown or are questioned in the evolving development context.

Ambiguity is a downright consequence of the inevitable differences in interpretation when multiple stakeholders are involved. Even the most obvious, strictly defined entity could still be assigned different meanings by different actors in relating it to, or deducing it in, the actors' real-world context or knowledge. This renders ambiguity a characteristic of the relation between an entity and an individual actor. Each actor has a unique frame of reference that is not only determined by the current status and development cycle, but is also influenced by expertise, interests, previous experience, education and factors such as mood. Joint procedural agreements, ranging from making minutes of a meeting to adopting industry standards can reduce this equivocality, but it cannot banish it. It goes without saying that the burden of ambiguity increases exponentially with the number of stakeholders involved, especially if the stakeholders are only loosely connected to the project.

In design, ambiguity is influenced by the state and condition of the resources used. Information related to such resources (ranging from documents to equipment) is often incomplete and indefinite. Moreover, stakeholders only might have access to partially overlapping information or even separate, detached information on the same resource. Even a

difference as simple as having two versions of the same document could cause misalignment and obfuscates mutual understanding. Given the contexts of the actors, even explicit and exchangeable information in a design project does not necessarily allow for univocal interpretation. Although scrupulous and controlled processing might case the manifestations of ambiguity, that is not the encompassing answer to deal with ambiguity. Moreover, the design process might be frustrated, particularly because it is the discrepancy in itself that can be instrumental in fostering new ideas, better comprehension of the design problem and better decision making. Rather than preventing ambiguity, this research aims at purposefully embracing the various denotations of information. This is not done by pointing out the emerging indefiniteness of information, but by explicitly taking into account the different perspectives on the information content.

5 DETERMINISTIC DECISIONS IN A NON-DETERMINISTIC ENVIRONMENT

The way in which information is currently used in development trajectories usually does not do justice to the non-deterministic nature of design. In order for information to be instrumental in decision making, the use and representation of that information should be tailored to its context and purpose. The characteristic indistinctnesses of design should therefore be manifest in the underlying information. Similar to tangible objects under construction, where the status is evidently visible, the information content (i.e. the product definition) should be seen as a workpiece. With this information as the pivot, volatility, ambiguity and uncertainty can become interrelated, meaningful and manageable aspects in the development context. Therefore, information can play a much more direct and active role in decision making. This section describes a generic approach towards incorporating the vuca aspects in information. Also, the potentialities of this approach are described.

Even in non-deterministic decisions, many of the evolvements of the information content are more or less self-explanatory in nature. This yields true for many steps that can be depicted as being routinely and predictable. For designers, assistance in addressing routine matters is beneficial, especially if that assistance can also address incertitudes. For this reason, this research introduces so-called mechanisms (see figure 1). By employing a what-if approach [11], mechanisms can assist designers, by taking on the more routine tasks involved in designing. Mechanisms can be considered as deterministic and autonomous means to reach decisions or make circumstances for decisions explicit, provided that the required input is available. In its broadest sense, mechanisms transform input into output according a predefined and well-established set of operations. These range from algorithms for e.g. strength analysis or workflow assessment, to process descriptions for risk assessment. The output of a mechanism can serve as input for other mechanisms. Therefore, a constellation of mechanisms can be seen as a mechanism in itself, generating more complex output like the assembly costs of a product.

Mechanisms process their input while taking into account three properties of that input: probability, validity and sensitivity. The probability can be used to address the uncertainty and reliability of the subset of information available. The validity of information expresses the terms and conditions that may apply, e.g. an exchange rate for raw material prizes, provisional information, or contextual boundaries that demarcate the legitimacy of the input. The mechanism itself also has a probability property, relating to the level of repeatability, accuracy and reliability of the mechanism itself. For each mechanism, the interdependency between variables determines the sensitivity of each input. Uncertain input factors that highly influence the output, will have a higher impact on the accuracy of the outcome than uncertain input factors with a minor influence on the output. By making such interdependencies explicit, decision makers can much better determine the effectiveness of efforts to reduce the uncertainty of specific inputs.

In decision making, mechanisms are made instrumental in providing insight in the possible consequences. It enables using information as a workpiece and aids in making the (im-)possibilities, contradictions and gaps in the evolving product definition explicit. Evincing the incertitudes that underlie that information not only results in a more realistic representation, but simultaneously reveals the scope and margins of that information. Collating new, emerging information stemming from the decision under consideration with e.g. the requirement specification that reflects the achieved consensus, produces insight and fosters design acumen. This enables continuous awareness on the alignment between the intended purpose and the evolving product definition.

6 CHALLENGE

In the context of this research, the aim is to convert the model of figure 1 into a practicable framework that supports designers and design teams in making decisions in a more deliberate manner. In this, the intangibilities of both the input and the decision making process as well as the exactitude of the output should be taken into account. In earlier research, a powerful underlying information structure for such a framework has already been addressed by means of the so-called actor network [12]. The actor network employs a non-hierarchical way of information structuring that ensures maximum flexibility while simultaneously allowing

meaningful information representation. With this, the actor network stresses the relevance of the information content, and allows for effective anchoring of decisions in that content.

Currently, the mathematical underpinnings of uncertainty and sensitivity in (deterministic) decisions and information content are being integrated in the actor network. With this, the foreseen preconditions can be met, and attention can shift to the way in which individual designers and design teams can purposefully address decision making while explicitly making the leverages of incertitudes instrumental. Here, the main challenge lies in establishing an interface with the designers and design team that enables them to focus on the design intent while spending efforts that are in line with the incertitudes of the process. Simultaneously, using those efforts to capture the design rationale is an essential side effect.

7 CONCLUDING REMARKS

Process-driven development methodologies function on a meta-level that is not always logically connected to the daily practise of product designers and engineers. When rigidly applied, process descriptions become oblique ways of working to arrive at design activities that add value to the product definition. This meta-level functioning can hamper designers in doing what they do best: solving problems by creating new products/solutions. Accountability based on progress regarding the process then becomes an unnecessary and inefficient way of control. Instead, the product definition itself should instigate the necessary design activities. Similar to a workpiece, information in development trajectories should serve the designer in considering the next best course of actions.

In this, design rationale should become the reason to record information instead of an imposed consequence and documentation afterwards. Consequently, the transformation of information instigates design activities. In acknowledging the elusiveness of decision making, this research aims to deliberately take into account the incertitudes; making it instruments instead of impediments. By explicitly addressing volatility, uncertainty and ambiguity, information is given a more true to nature representation: a non-definitive status from which the incertitudes can easily be read. For now, this does not yet overthrow the way in which products are developed, but it does substantiate an understanding of decision accuracy, reliability and sensitivity. For the short term, it may change the way in which designers are supported in reaching decisions. In the long run, however, using the information base as the pivot of development cycles can open up new ways of using PLM, CAD and other tools in design cycles.

8 REFERENCES

[1] Lutters, E., van Houten, F.J.A.M., Bernard, A., Mermoz, E., Schutte, C.S.L., 2014, Tools and techniques for product design, CIRP Annals - Manufacturing Technology, 63/2:607–630.

[2] Koen, P., Ajamian, G., Burkart, R., Clamen, A., Davidson, J., et al., 2001, Providing Clarity and a Common Language to the “Fuzzy Front End,” Research-Technology Management, 44/2:46–55.

[3] Smith, P.G., Reinertsen, D. G., 1997, Developing products in half the time: new rules, new tools, 2nd editio. New York: John Wiley And Sons Ltd.

[4] Cooper, R.G., 2008, Perspective: The stage-gates? idea-to-launch process - Update, what’s new, and NexGen systems, Journal of Product Innovation Management, 25/3:213–232.

[5] Dorst, K., 2011, The core of ‘design thinking’ and its application, Design Studies, 32/6:521–532.

[6] Culley, S.J., 2014, Revisiting Design as an Information Processing Activity, pp. 371–394.

[7] Stiehm, Hicks, J., Townsend, N.W., 2002, The U.S. Army War College: Military Education in a Democracy, The U.S. Army War College: Military Education in a Democracy, p. 6.

[8] Gigerenzer, G., Gaissmaier, W., 2011, Heuristic decision making., Annual review of psychology, 62:451–482.

[9] Law, J., 1992, Notes on the theory of the actor-network: Ordering, strategy, and heterogeneity, Systems Practice, 5/4:379–393.

[10] Lutters, D., Van Houten, F.J.A.M., 2013, Ambiguity and uncertainty of Requirements in Product Development, COMA’13; International Conference on Competitive Manufacturing.

[11] Lutters, D., Vaneker, T.H.J., van Houten, F.J.A.M., 2004, ‘What-if’ design: a synthesis method in the design process, CIRP Annals - Manufacturing Technology, 53/1:113–116.

[12] Lutters, E., Dankers, W., Oude Luttikhuis, E., De Lange, J., 2014, Network based requirement specification, CIRP Annals - Manuf. Technology, 63/1:133–136.

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