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Engineering Better Decisions: Exploring Influencing Factors of Behavioral Economics on SGE - System Generation Engineering

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Abstract: Decisions made during product development, from ideation to market readiness, are pivotal. Focusing on SGE – System Generation Engineering, this study investigates the impact of behavioral economics on decision processes in product development. It identifies 53 influencing factors, such as default options, framing and reminders from the nudging approach, categorized into clusters crucial for shaping decision architectures. By recognizing good decision characteristics, such as coherence, efficiency and effectiveness leveraging behavioral insights, the paper advocates for informed decision-making to drive innovation in the context of SGE.

Keywords: Product Development; Innovation Management; Behavioral Economics; Decision Making; Nudging

1 Context & Motivation

To survive within a dynamic market, companies must continuously produce new innovations. There are several phases in the product development process, starting from the initial idea to a market-ready product, in which important and far-reaching decisions are made under various uncertainties. The high impact of suboptimal and wrong decisions requires good decisions to be made by product engineers and product development teams at an early stage of the development process.

Every day, decisions are made influenced by unique individual personalities, emotions, and circumstances, whether thoroughly prepared or intuitively and unconsciously. Because of the multitude of diverse influencing factors, it is not always feasible to make optimal decisions, and establishing an optimal decision-making framework can prove to be challenging. Various studies in behavioral economics highlight that a better understanding of decision-making processes can contribute to making better decisions (Kahneman and Tversky, 2013; Gächter, 2009; Ariely, 2008).

According to Kahneman et al. (2021) cognitive distortions (bias) and random scattering (noise) affect decision outcomes. For example, the emotions or personal values of decision-makers yield divergent judgments in similar situations. For instance, federal judges in the US have imposed sentences ranging from 15 days to 15 years for similar offenses. Ariely (2008) explains the behavior of people under certain conditions using behavioral experiments and determines that decisions in the "hot" (emotional) state and "cold" (rational) state led to significant deviations.

Is it possible to utilize the findings of behavioral economics to influence the behavior of individuals systematically? Thaler and Sunstein (2021) introduced the term nudge and the related nudging approach, which encompasses all aspects of the decision architecture that alter people's behavior in a predictable way. However, a nudge must be subtle and must not limit alternative options. The essential economic incentive must remain and the intervention in the decision-making process must be economically viable to avoid (Thaler and Sunstein, 2021).

Due to the fact that the majority of decisions in the product development process are made by people, the logical consequence is to look at the decision-making behavior (Ulrich and Eppinger, 2016). Therefore this research effort focuses on holistically collecting influencing factors for decisions and analyzing them in detail - including the application to the decision-making architecture of development teams. The analyzed factors are intended to serve as a library that enables organizations and researchers to understand their specific situation as best as possible, select targeted recommendations for action, and pursue their operationalization based on the corresponding applications. This research work thus contributes to the sustainable improvement of decisions in product development and explores how the findings of behavioral economics can be utilized to systematically influence the behavior of individuals in the context of SGE – System Generation Engineering.

1.1 Decisions in SGE - System Generation Engineering

Major decisions arise during the development of a new product generation, encompassing considerations such as which subsystems to adopt, what adaptations are necessary, and where novel solution principles are required. The SGE - System Generation Engineering approach of Albers et al. (2021) provides a realistic representation of system or product development in industrial practice, with the idea that new products and systems are not developed entirely without references in terms of economic and risk management considerations (Albers et al., 2021; Albers et al., 2018; Bursac et al., 2018). New product and system generations are often based on an existing (ideally established on the market) reference model, aiming to mitigate uncertainty, by making minimal adjustments to an already existing solution (Eckert et al., 2010). Improving existing products and systems is therefore the predominant type of product and system development (Eckert et al., 2010). When subsystems are adopted, the SGE approach refers to a carryover variation (CV). Existing solutions of a reference product or system are adopted into the new product or system generation (G_i) and, under certain circumstances, adapted to the requirements at the relevant interfaces (Albers et al., 2015). Typically, a novel solution principle for a subsystem can be designed in two ways: Either by the activity of principle variation (PV) or by the activity of embodiment variation (EV) – whereby principle variation is always accompanied with EV (Albers et al., 2018). Under certain circumstances, a carryover variation (CV) can also be transformed into a new solution principle - for example, if a function from another system or subsystem is "misused"/"alienated". An innovation, in the context of the SGE approach according to Albers et al., is made up of embodiment variation (EV), principle variation (PV), and carryover variation (CV) (Albers and Rapp, 2021).

Depending on given requirements and circumstances, product engineers have to decide on the amount of carryover variation (CV), principle variation (PV), and embodiment variation (EV) in terms of a strategic system and subsystem design of a new product or system generation. A high adoption rate of decentralized subsystems (high amount of carryover variation) can, for instance, accelerate the development process in product development. As part of this process, the developed solutions must be validated and evaluated against the initial target system as well as relevant technical and economic parameters of the action system, like producibility, necessary resources, etc. (Hirschter et al., 2018). Consequently, pivotal decisions are early in the product development process affecting subsequent processes. Thus, ensuring good decisions at an early stage concerning the available resources, such as financial resources, available time or personnel skills and capacities is crucial (Albers et al., 2017; Bursac et al., 2018). However, the quality of a decision can be evaluated independently of its outcome (Elwyn and Miron-Shatz, 2010). In order to thrive in a dynamic market, companies must consistently generate new innovations. The imperative to innovate is driving a rise in agile working methods, thereby altering decision-making patterns and the architecture of decision-making (Schoeck and Batora et al., 2023a; Schoeck and Batora et al., 2023b; Zuefle et al., 2023).

1.2 Behavioral Economics

Standard economic theories, like homo economicus, assume that the decision-maker is strictly characterized by rational and self-interested action aimed solely at profit maximization (Hochman and Ariely, 2015). However, these models, particularly the homo economicus construct, are considered unrealistic when applied to real economic situations (Dreher, 2022). Empirical studies demonstrate that decision-makers do not always act and decide rationally (Ariely, 2008; Kahneman, 2011).

The work of Kahneman, Tversky and Ariely in behavioral economics illustrates how decision-makers tend to make irrational decisions (Ariely, 2008; Kahneman and Tversky, 2013; Kahneman, 2011). For example, decision-makers tend to display a risk-averse manner in scenarios involving potential gains and are more likely to favor risky options in situations of certain loss - the willingness to take risks therefore increases with the size of the gain (Bursac et al., 2018). Further research conducted by Kahneman or Ariely shows that human decisions are – influenced by emotional and social factors - often irrational and determined (Ariely, 2008). Decisions can also be distorted by confounding factors such as "noise" or "bias" (Kahneman et al., 2021; Bursac et al., 2018).

Kahneman (2011) classifies decision-making systems into two categories in “Thinking Fast, Thinking Slow”: System 1 (thinking fast) operates intuitively, automatically, and unconsciously, with decision-making processes based on associations and similarities (heuristics are an example of these decision-making patterns), while system 2 (thinking slow), which can be compared to the theory of homo economicus, functions consciously, slowly, in a controlled, static and laborious manner, albeit only activating when required by the circumstances (Shleifer, 2012). According to Kahneman (2011), most decisions are primarily governed by System 1. In addition to the individual personality of the decision-maker, numerous other factors and decision-making patterns influence choices. Consequently, the central aim of behavioral economics is to identify relevant and realistic influencing factors that affect people's decisions (Hochman and Ariely, 2015; Kahneman, 2011).

The intuitive and sometimes irrational behavior of decision-makers, some of which can be found in System 1, can be explained using decision patterns, such as heuristics, and predicted to a certain extent under certain conditions (Hochman and Ariely, 2015; Ariely, 2008; Kahneman, 2011; Bursac et al., 2018). Furthermore, decisions can be influenced using nudges and predicted based on statistical tendencies (Hummel and Maedche, 2019). Given these considerations and a targeted examination of decision-making phases in product development processes, the question arises as to whether the decision-making architecture can be designed in such a way that decision-makers can be "guided" to a good decision with low interference and without any prohibitions on alternatives.

As behavioral economics and product development have traditionally been studied in isolation, this research endeavors to comprehensively gather influencing factors for decisions and meticulously analyze them. This includes examining their application to the decision-making processes within development teams' architecture.

2 Research Gap & Target

This research study contributes to the investigation of the extent to which the quality of decisions can be improved by specifically influencing behavioral economics within SGE – System Generation Engineering. For this purpose, the behavior of decision-makers in product development is analyzed based on an extensive literature review, identifying decision patterns, characteristics, and influencing factors. While the literature review primarily highlights the dominant influence of behavioral economics on marketing decisions, its impact on decision architecture extends to various operational domains, including healthcare, environmental protection, and finance. (Mirsch et al., 2018; Kenning et al., 2016).

According to Kenning et al. (2016), Sunstein and Thaler's nudging approach can be described as a systematic approach to influencing the decision-making behavior of a decision-maker without restricting alternatives. In the general context of behavioral economics, the objective of nudging is to improve the efficiency and effectiveness, e.g. of political strategies and measures, for the benefit of both, the individual consumer and society. A classic example of nudging with a “political strategy” is health warning labels on cigarette packs, which show potential buyers the consequences of smoking and are intended to encourage them to make a corresponding decision. The purchase is not prohibited, so customers remain free to choose. Another example from everyday life is GPS, which usually shows the best route to take while allowing users to freely choose an alternative route (Kenning et al., 2016). Nudging can also be successfully implemented in many other areas (Mirsch et al., 2018; Kenning et al., 2016). This suggests that implementing nudges into product creation processes can effectively enhance the results of product development and innovation management also concerning the corporate strategy and objectives.

This study aims to examine the potential of applying research findings in the context of behavioral economics to shape the behavior of individuals in the context of product development in a systematic way. This study seeks to investigate the potential application of nudging in product development, particularly within the SGE framework, to steer decision-makers towards optimal or good decisions – to move closer to addressing the research gap.

2.1 Research Questions

The following research questions derived based on the research needs serve to operationalize the underlying objective of this work:

1. What are the characteristics defining good decisions in the product creation process?

2. What influencing factors can be used to effectively shape decisions in the product creation process?

3. How can the concept of influencing decision-making patterns be transferred to the product creation process?

2.2 Research Design

To systematically address the research questions, the "Design Research Methodology" (DRM) framework according to Blessing and Chakrabarti (2009) was adopted. The literature review was conducted using various methods. Initially, the scoping review method was utilized to obtain a comprehensive overview of the two research disciplines and to develop the first phase of the DRM framework, the clarification of the research object. Based on the results, the research gap was identified. Afterward, a content analysis was conducted using specific search terms such as "nudging", "decision making in SGE", "heuristics", "quality of decision making", etc. to identify relevant sources and studies. By combining the research gap and the supplementary content analysis, research hypotheses were developed from which the research questions were subsequently derived.

In the second phase of the DRM, the descriptive study 1, influencing factors that influence decisions in a general context were identified on the base of the holistic, systematic literature review (> 70 research sources) and the analysis of results from previous research studies in behavioral economics. Based on this, the IF_{BE} - Map was developed, which served as the basis for the third phase of the DRM, the prescriptive study. The identified and analyzed influencing factors were focused on the effects and applications in SGE development processes, summarized in tabular form in the $IF_{BE,SGE}$ - Map and can thus be used for further research projects or use in industrial practice. As a result, 53 relevant influencing factors were identified, which have an impact on the decision architecture of the product creation process. For a better overview, the influencing factors were categorized into five clusters. The actual effectiveness of the identified influencing factors from this work will be utilized and validated in a broad empirical study in the form of an online survey. The results of the study are planned to be presented in a further paper.

Following the comprehensive literature research and the targeted application of the content analysis, categories were identified that could be used to classify the influencing factors into suitable clusters. Based on a logical grouping according to thematic proximity and a hierarchical cluster analysis the corresponding clusters "Nudging" (Thaler and Sunstein, 2021; Polak et al., 2008; Kenning et al., 2016; Feild, 2015; Arntz, 2017), "Individual" (Ariely, 2008; Mendes et al., 2019; von Thun et al., 2003; Kahneman, 2015; Kahneman et al., 2021), "Heuristics" (Tversky and Kahneman, 1974; Gigerenzer and Gaissmaier, 2006; Kahneman, 2015), "Group" (Hofstede, 2011; Stankau, 2019; Bion, 2018; Forsyth, 2014; Hirokawa and Rost, 1992) and "Stakeholder" (Rueda-Manzanares et al. 2008; Majava, 2014; Esper et al., 2010) were established. Additionally, a brainstorming session was used to add influencing factors with sufficient thematic proximity to the respective clusters. A clear separation of the respective clusters proves to be challenging. It should be noted that it is therefore possible that certain influencing factors, such as the anchor effect, could also be assigned to another cluster, such as the "heuristics" cluster. To avoid redundancies in the form of duplications, the influencing factors were assigned to the corresponding clusters based on their thematic proximity (from the authors' perspective).

The objective of this research is to determine which influencing factors indicate potential for successfully shaping decision-making behavior. The targeted focus on decision-making in the context of SGE – System Generation Engineering and in particular in the early phase of product and system generation engineering should be considered as a contribution to closing the research gap. (Albers et al., 2023)

3 Findings

Characteristics that favor a good decision can be understood as a "measured value" of the quality of a decision. The influencing factors, in turn, can be used as a "tool" when designing the decision architecture to achieve the desired decision behavior in product development, which is known from behavioral economics.

3.1 Characteristics Defining Good Decisions in the Product Creation Process

In terms of improving the decision quality, the literature research revealed significant characteristics that favor a good decision in product development. These characteristics encompass the quality of available information (relevant for decision-preparing activities) and the decision-maker attributes, such as competence, as well as the recognition and thorough evaluation of all relevant alternatives, considering potential outcomes and consequences, and considering the risk-reward ratio (Bursac et al., 2018; Raghunathan, 1999). Good decisions should be consistent and fulfill all the requirements set (Vlek, 1984) while being effective and efficient. In terms of achieving objectives in the product creation process, this means that decisions are chosen to be implemented in the best possible way concerning the requirements formulated in the target system using the knowledge base and the given possibilities of the action system.

3.2 The $IF_{BE,SGE}$-Map - Schematic Structure

The literature review was used to identify influencing factors that have a significant impact on decisions. These factors were then considered in the context of the SGE. The factors that promise a high potential for influencing decisions in the product creation processes were selected and summarized in the so-called $IF_{BE,SGE}$-Map. Due to the successful application of the nudging approach in various areas of behavioral economics, it is expected that the integration of these factors into the decision-making processes of the SGE could also promise significant success. The potential of the additionally identified influencing factors is anticipated due to the logical causal relationship that factors influencing decision-making in behavioral economics could also have similar effects in system development processes. Since human decision-makers are involved in both contexts, it is assumed that similar factors could have comparable relevance and effectiveness. Furthermore, the identified factors were validated with the help of expert interviews to ensure that the identified factors are relevant and significant. The table of influencing factors was presented to the experts and validated with the help of guiding questions. The guiding questions consisted of quantitative and qualitative questions such as "Is the list of identified influencing factors complete? Are there any influencing factors that are superfluous or missing from the list?", "Can a potential for influencing decision-making in SGE development processes be anticipated in the identified influencing factors?", as well as "Are there influencing factors that are more effective in influencing decision-making compared to other factors?". The feedback from the experts resulted in the prioritization of the nudging factors, as these promise a higher potential for influence than, for example, influencing factors such as leadership style, according to the two experts interviewed. In addition, a conceptualization of a card game for training purposes based on the table of influencing factors ($IF_{BE,SGE}$-Map) proposed, which will be discussed in another planned scientific contribution by the authors.

The expert interviews represent a suitable method as the selected experts have specialized knowledge from relevant research fields (e.g. the application of heuristic in SGE and experience from the industry to assess the importance and relevance of the factors). The inclusion of expert opinions strengthens the validity and reliability of the list, as it is based on substantial expertise. This ensures the objectivity and quality of the final list of influencing factors. The complete table and corresponding sources are available upon request to the authors.

The schematic structure of the $IF_{BE,SGE}$-Map is described in the following.

The map comprises 53 influencing factors which, according to the authors, have a significant degree of potential influence on the behavior of decision-makers in the SGE. Not all of the identified factors have the same degree of potential. Some of the influencing factors can be used more effectively than others. The factors were divided into five clusters to provide a better overview. The allocation of the influencing factors to the respective clusters can be found in the first two columns of the table and summarized as follows: 1. nudging (11 factors), 2. individual (26 factors), 3. heuristics (5 factors), 4. group (7 factors) and 5. stakeholders (4 factors). In the context of the SGE, the clusters summarize the most important entities (individual, group, and stakeholder) from which decisions originate, alongside techniques (heuristics and nudges) utilized to make or influence decisions.

To give the reader a tangible understanding of the respective factors, these are briefly described in the column “Description” of the table and explained with a general example in the column “General Application Examples”. The enclosed sources can be found in the column “Source” and be used for further research to gain a deeper understanding of the respective factors.

In addition, literature research was used to identify and analyze decision-making patterns that arise when using the identified influencing factors in behavioral economics. This decision-making behavior should be used in the relevant phases of the SGE. To this end, areas of application in the SGE were identified in which the potential of the influencing factors promises an analogous effect. These were compiled as examples for the respective factors in "Field of application (SGE)".

In the "Possible Application and Effects" column, possible solutions and implementation proposals for the respective factors are formulated based on the above assumptions, as well as countermeasures for undesirable effects of the influencing factors. These proposals do not claim to be exhaustive but rather serve as conceivable application approaches.

The map of factors influencing decisions, and in particular the “Possible Applications and Effects” column, can therefore be used as a guiding resource for influencing decision-making processes in product development. However, the more information about the respective decision-maker is known, the more effectively the decision architecture can be designed.

In this context, in addition to the $IF_{BE,SGE}$-Map, it can be deduced from the literature research that the more is known about the decision maker and their personality, the more effectively the decision architecture can be designed (Thaler and Sunstein, 2021). It should also be mentioned that the decision-maker can also be the decision architect. However, the effect of the generated influence, also called "self-nudging", is lower when the decision maker is also the decision architect, compared to when the decision architect is someone other than oneself.

3.3 The $IF_{BE,SGE}$-Map - Exemplary Presentation

This section outlines the structure and principle of the $IF_{BE,SGE}$-Map through the presentation of selected influencing factors on decisions. Three factors from the nudging cluster and one each from the individual and heuristics clusters are presented as examples in the following. The $IF_{BE,SGE}$-Map was created to transparently conceptualize and describe promising implementation proposals for good decisions and thus enable a joint analysis for future studies. An excerpt from the map is used to illustrate and explain the concept of the map.

Cluster	Influencing Factors	Description	Source	General Application Examples	Field of Application (SGE)	Possible Applications and Effects
1. Nudging	1.1. Anchor (Effect)	The anchor effect is a heuristic judgment bias. This effect describes the phenomenon that people are unconsciously influenced by previously mentioned numbers (anchors) when making numerical estimates.	Arntz (2017) Nasher (2018)	Negotiations (e.g. salary increase)	Early phases of a development process (e.g. ideation process)	Use the anchor effect for yourself: Example: Numerical influence through targets - Set Goal: Cost reduction through the specification of planning costs "Budget is €50,000 (instead of €200,000)". … Counteract the anchor effect: Example 1: Raising awareness of the effect. Example 2: Thorough research (this allows the initial anchor to be quantified and relativized). …
	1.2. Framing	The "framing" of events in interpretative grids and narrative patterns. The desired topic can be emphasized through the selected framing.	Thaler & Sunstein (2008)	Example 1: Verbal: 20% fat content vs. 80% fat-free (food description). Example 2: Visual: Pictures on cigarette packaging.	Entire development process	Verbal: Example 1: Focus through alternative formulations -> Increase motivation: e.g. use "challenge" instead of "difficulty" -> Presentation of results (e.g. to stakeholders): e.g. instead of 20% error rate, 80% hit rate, etc. … Visual: Example 1: Active spatial design (e.g. through posters, exhibition of prototypes, videos, etc.) …
	1.3. Reminder	A thing that causes someone to remember something	Thaler & Sunstein (2008)	Smartwatch (steps), push notification for emails etc.	Entire development process	… Example 3: Visualization (e.g. through spatial design) -> Reminders by means of posters, whiteboards, etc. with e.g. guiding principles, goals, requirements, company ethics, etc. Example 4: Control -> At the end of each completed process phase, a visual reminder can be introduced where, for example, the remaining planned credit for the project is displayed. This may lead to interim validation, early iteration steps and important corrections.
	…	…	…	…	…	…
2. Individual	…	…	…	…	…	…
	2.19. Noise	Undesirable random scatter/ fluctuations in the assessment of the same problem (Kahneman).	Kahneman, Sibony & Sunstein (2021)	… In medicine: Doctors arrive at different diagnoses for the same patient, especially in psychiatry. …	Entire development process (Ideally, noise is recognized in the early phase of the PGE and eliminated in the best possible way).	Actively use noise: Example 1: Creative, innovative and diverse solutions through diversity (e.g. with the help of brainstorming or mind mapping). … Countermeasure for noise: Example: regular "noise audits" -> Areas in which noise is dominant can be identified. -> Create a trusting environment in which employees can exchange ideas and "correct" each other if necessary.
	…	…	…	…	…	…
3. Heuristics	…	…	…	…	…	…
	3.4. Heuristic Questions	If a satisfactory answer to a difficult question is not found quickly, the cognitive-intuitive area of the brain (system 1) finds a similar question that is simpler and answers it instead.	Kahneman (2015)	Should I buy VW shares? - difficult question. Do I like VW vehicles? - easier question.	Entire development process (Rather early phases of the development process).	Example 1: Define the problem and provide clarity -> Divide complex problem into many small, known problems (identify relevant aspects and requirements). … Example 2: "Mental shotgun" by Kahneman (2015) -> Fast flow of ideas (all ideas are written down) -> Diversity of ideas. -> Organize and evaluate with the help of the analytical and reflective system. …
	…	…	…	…	…	…
…	…	…	…	…	…	…

Figure 1. Exemplary representation of a selection of the $IF_{BE,SGE}$-Map linked to the examples in subsection 3.3. The complete table and corresponding sources are available upon request to the authors.

(1) Nudging – (1.1) Anchor

The anchor effect is a cognitive bias in which people tend to have their decisions strongly influenced by an initially presented value or "anchor", even if this value is completely arbitrary. This effect can often be observed in negotiation discussions (Nasher, 2018). If the anchor effect is considered in the context of the SGE, the possibility of its relevance in idea generation processes appears to play a conceivable role. This effect can be particularly important at the beginning of the development of a new product generation, as decisions in this phase have a significant impact on downstream processes. For example, if a high initial budget is specified for a new project, and thus a high budget for the procurement of relevant reference models, it can be deduced from various studies that the willingness to pay more for the same product or system (in this case, for example, a potential reference product or system) is higher than with a smaller initial budget due to the anchor effect (Simonson and Drolet, 2004). The potential of the anchor effect can be used in the context of the SGE to reduce costs. For example, only part of the possible budget for a project can be specified as a guide in order to initially set a small numerical value as an "anchor". If the aim is to prevent the anchor effect, this can be initiated by raising employee awareness. Extended research can be used to quantify and relativize the initial anchor.

(1) Nudging – (1.2) Framing

Framing can be used to emphasize a desired topic. In everyday life, this effect can be observed in the supermarket. It is not uncommon to find labels such as "80% fat-free". However, if the focus is to be explicitly placed on the fat content, the label "20% amount of fat" would be conceivable in line with the example mentioned. The actual fat content is the same in both references. If the framing effect is considered in the context of the SGE, it can occur or be actively used in all phases of the development process. Framing can be used both verbally and visually. One of the verbal possibilities to actively use the effect is the respective formulation and the desired "emphasis" of a topic. For example, in a meeting, the challenge can be emphasized instead of the difficulty in order to increase employee motivation. Similarly, the strengths of a product or system can be emphasized in discussions with stakeholders instead of highlighting the weaknesses, for example by mentioning and emphasizing the success rate instead of the error rate. The framing effect can also be used visually through active spatial design. For example, posters with guiding principles or inspiring motifs can be placed in the room to draw attention to specific topics, such as sustainability. This can motivate employees on the one hand and focus on the desired results on the other.

(1) Nudging – (1.3) Reminder

A reminder is a note that serves to remind you of upcoming events, appointments, or tasks. The classic reminder, e.g. via an alarm clock or a push notification from a smartwatch, is very common in everyday life. If the reminder is considered in the context of the SGE, it can be placed in the spatial design in a similar way to the framing effect. Requirements, framework conditions, goals, etc. can be placed in the room, e.g. written on a whiteboard, to visually remind employees of the relevant aspects of a target system, e.g. during an idea generation process. This can direct the employees' focus on the goals set and lead to better and more consistent decision-making. This may eliminate the need for downstream iterative processes and thus save costs, as employees are reminded of the relevant factors of the target system during the initial process. In addition, the reminder can also be used as a control tool in which, for example, the remaining budget is checked after each completed development phase (using a calculation program). This can lead to interim validation, early iteration steps, or important corrections.

(2) Individual – (2.19) Noise

Noise refers to the variation in decisions that occur due to randomness or unexplained fluctuations. Variability or fluctuations in decision-making refer to unexplained variations in people's decisions that can lead to inconsistent outcomes even though the decision-makers have similar information. When people make decisions, there are almost always undesirable fluctuations, known as noise (Kahneman et al., 2021). These are due to various individual factors, such as personal well-being and mood/emotion, knowledge, individual preferences, biases, and many more. In everyday life, noise can be observed, for example, when making a diagnosis. It is not uncommon for different doctors to determine different diagnoses for the same patient. In the SGE, noise can occur at any stage of development. Noise audits are recommended as a remedy (Kahneman et al., 2021). A noise audit involves examining and analyzing decision-making processes for systematic fluctuations and unexplained variations. The goal of such an audit would be to identify the sources of noise or variation in decisions and develop measures to reduce these sources of noise. By creating an environment of trust, product engineers and product development teams can identify discrepancies in decisions and correct each other if necessary. This could help to promote consistent and reliable decisions and minimize the negative impact of noise in decision-making processes.

However, noise can also lead to creative, innovative, and diverse solutions through diversity. This can be implemented with the help of brainstorming and mind mapping, for example. Noise can also have a positive effect on the learning curve and therefore on knowledge management, firstly by identifying any necessary adjustments at an early stage and secondly by increasing the acceptance of errors.

(3) Heuristics – (3.4) Heuristic Questions

Heuristic questions can be roughly understood as an intuitive simplification of a complex/difficult question. However, it should be noted that the answer to the alternative new, less complex, and less difficult question created by the cognitive intuitive part of our brain does not necessarily provide an adequate answer to the original complex question. A complex/difficult question could be: "Should I buy shares in VW?". An analogous heuristic question would be, for example, "Do I like VW cars?". It is trivial to recognize that the answer to the latter question does not necessarily have to be the same as the answer to the first and somewhat more difficult question. Such heuristic questions can also be found in the SGE, e.g. in requirements analysis, idea generation, and evaluation as well as prototyping. The heuristic questions can be actively used in a variety of ways. These can help to define a problem and create clarity. A complex problem can be broken down into smaller and less complex sub-problems using heuristic questions. In this case, relevant aspects and requirements can be identified. The heuristic questions provide a wide range of options, allowing alternatives to be defined at the same time.

The $IF_{BE,SGE}$-Map is intended to represent the first attempt at a conceptual model that transfers the influencing factors and decision patterns from behavioral economics into the development process of the SGE. Areas of application in the SGE are shown in which the potential for successful use of the respective influencing factors appears promising. In addition, concrete application examples are proposed that promise a high potential for success.

4 Conclusion

Every day, decisions in the product and system development process are influenced by unique individual personalities, emotions, and circumstances, whether thoroughly prepared or intuitively and unconsciously. Due to the wide range of different influencing factors, good decisions are not always made and it's not easy to create a decision architecture with optimal circumstances. Suboptimal or wrong decisions often affect the success of the product creation process regarding time, costs, and quality, especially in product engineering. Good decisions are fundamental, especially in the area of innovation management as part of product engineering, as poor decisions are often associated with the failure of inventions.

As a result of this study, success factors were identified and transferred to the product creation process in the context of the model of SGE - System Generation Engineering.

In the product creation process, and especially in the early stages of the development of a new product or system generation, pivotal decisions are made that have an impact on subsequent processes. Hence, prioritizing good decisions early on, considering available resources, is paramount. As the literature research shows, the quality of decisions can be assessed independently of their outcome. For this reason, the focus should not remain on the outcome, but on the characteristics of a good decision. To this end, characteristic features defining the qualitative value of a decision were identified, with effectiveness and efficiency emerging as pivotal aspects.

This research study also identified influencing factors that have an impact on decision-making behavior in product development. These were worked out in tabular form and elaborated in the context of product development. Focused on enhancing decision quality, the recommendations regarding the use of influencing factors were designed to either actively bolster conditions for sound decision-making or sensitize decision-makers to potential negative impacts, mitigating adverse effects. The suggestions for implementation are merely indicative and do not cover the entire possible scope of action. Ultimately, it is up to the decision architect - product engineers or (innovation) managers in the context of product development - to select the framework conditions and the necessary applications of the influencing factors in such a way that these can be effectively implemented regarding quality improvement. In addition to the map of influencing factors on decisions, it can be deduced from the underlying literature research that the more is known about the decision maker and their personality, the more effectively the decision architecture can be designed and the greater the prospect of successful and adequate influence (Thaler and Sunstein, 2021).

5 Outlook

Future research endeavors should empirically explore the correlation between identified influencing factors and their impact on decision-making. Validating the fundamental effect of these factors and assessing proposed applications will be essential in subsequent studies. The objective is to ascertain whether the targeted utilization of selected influencing factors in decision architecture enhances decision quality. To this end, a broad online survey incorporating case studies will be conducted. The findings of this research effort suggest that the targeted implementation of nudging techniques can effectively enhance product creation processes, thereby improving the results of product development and innovation management. To analyze the extent to which influencing factors, like different nudges, improve patterns and decisions of product engineers and product development teams, a live-lab study based on this research effort will be conducted in the future. In this context, live labs are a good environment to analyze further decision heuristics in the agile development of mechatronic systems (Bursac et al., 2023).

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