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Challenges, Potentials and Success Factors in Automotive HMI Concept Development in the Early Phase in the Model of PGE – Product Generation Engineering

Sebastian Hünemeyer[1], Florian Reichelt[2], Simon Rapp[1], Albert Albers[1], Thomas Maier[2]

[1]Karlsruhe Institute of Technology
Sebastian.huenemeyer@partner.kit.edu; Simon.rapp@kit.edu; Albert.albers@kit.edu
[2]University of Stuttgart
Florian.reichelt@iktd.uni-stuttgart.de; Thomas.maier@iktd.uni-stuttgart.de

Abstract

The importance of UX is widely recognized by product developers among automotive OEMs. A distinctive UX shaping the brand is an important goal in the development of a new product generation. Trends such as advancing digitalization and connectivity of products open up numerous innovation potentials for UX developers. This contribution focuses on in-vehicle UX in terms of designing interactions between the vehicle and the user. In academia, theories and models to explain the phenomenon of user experience are widespread. Furthermore, numerous research approaches in the field of engineering sciences pursue the goal of making user experience measurable and evaluable. However, in the course of our literature review, we found that there is currently a lack of tools and methods that support product developers in eliciting user needs and subsequently synthesizing concepts. For this purpose, particularly the early phase of product development offers required creative freedom. However, this phase is also characterized by a high degree of uncertainty. These circumstances raise the question of which challenges product developers face when designing interactions. This paper aims to contribute to this question through a two-step descriptive analysis in cooperation with a leading German automotive group. Based on a literature review, challenges and strategic potentials were first discussed with UX experts in a workshop (n=11). From these results, a total of 28 hypotheses were derived, which were then evaluated in a second step in an online survey (n=45) by a broad set of experts. Subsequently, the challenges identified in this way were translated into four qualitative success factors to provide product developers with concrete recommendations for action. Additionally, a total of seven requirements were extracted from these factors to help product development research close the identified research gap in further prescriptive studies.

Keywords: User Experience, Automotive UX, Early Phase of Product Development, Interaction Design, Challenges, Success Factors, Methods, PGE – Product Generation Engineering

1 Introduction

Numerous studies confirm the growing importance of a distinctive user experience as a differentiating factor in the competitive global automotive markets. Schröer (2013) in fact postulates that the benefit of interactive products only arises through consideration of the user interfaces that make the actual interaction possible in the first place. Meanwhile, automotive product development is undergoing profound change: technological and market trends such as digitization or automated driving are not only increasing innovation opportunities, but also complexity in product development. At the same time, new players entering the market are increasing the pressure on UX developers in established automotive groups. Both a curse and a blessing is the fact that the product attribute user experience is perceived very subjectively and thus there are few objective requirements for product development. Conversely, this gives developers a great deal of creative freedom. The purpose of this publication is to analyze how automotive developers should deal with this complexity. The main focus is on methodical support for the elicitation of user needs and requirements from contextual developments and their transfer into concept development. To answer this question, it is first necessary to have a comprehensive understanding of the research field of user experience and its significance for the automotive industry.

2 Background (State of Research)

2.1 Usability and UX and its Role in the Automotive Industry

UX is an umbrella term considering a person's entire interaction with a product and includes thoughts, feelings, and perceptions that result from that interaction (Albert and Tullis, 2013). In the ISO 9241-210, UX is defined as ''a person's perceptions and responses that result from the use or anticipated use of a product, system, or service''. The term originates from the concept of usability, thus it's scope goes beyond the notion of usability. In academia, it is commonly agreed that the general objective of UX is to provide positive experiences instead of just avoiding bad ones by improving usability when interacting with a product (Roto et al., 2009; Saucken et al., 2013). Kim et al. (2011) therefore elaborate on fulfilling psychological needs to create a positive UX. The user's internal state, the system's functional, aesthetic, and symbolic attributes, and the environment and context of use influence the perceived UX (Hassenzahl & Tractinsky, 2006; Saucken et al., 2013a). Such a comprehensive and diverse understanding of UX leads to challenges in the practical implementation (Väänänen et al., 2008). Pettersson & Ju (2017) emphasize the in-vehicle UX as particularly relevant for product engineers in the automotive industry. This aspect mainly focuses on the interaction between the driver (user) and the interactive product functions of the vehicle (Kun et al., 2016). Interaction is a highly context-sensitive process and therefore influenced by the driving scene and other environmental factors (Harvey et al., 2010). Consequently, product engineers need to incorporate the influence of the driving situation in addition to the physical interface and interaction design (Löcken et al., 2017). This dependency on the context increases the overall complexity of the design task (Fastrez and Haué, 2008). Therefore, impeccable and continuous communication between driver and car is crucial in terms of in-vehicle UX and user perception. This paper being focused on the automotive product development process, we focus on the practical implementation of UX principles, in particular on the tools and methods used by UX practitioners. To accommodate the high degree of complexity, OEMs are increasingly leveraging specialized development teams responsible for orchestrating them into a positive overall experience in the vehicle. The state of research provides numerous theoretical descriptions of UX as well as methods for measuring and evaluating it throughout the product development process. However, there is a deficit of tools and methods supporting the synthesis of promising concepts to support a positive UX especially in the Early Phase of product development (Saucken et al., 2013b).

2.2 Interaction Design in the Early Phase of Product Development

The product development paradox highlights that in the Early Phase of Product Development, a lot can be changed, but the effects of the decisions are hardly known; while in later phases, a lot can be assessed in more detail, but hardly anything can be changed (Albers et al., 2016). Additionally, case studies indicate that decisions made in the early phase of product development have a large impact on future product attributes such as perceived product quality or cost, and thus strongly determine project success (Cooper & Kleinschmidt, 1993). The sometimes used term “fuzzy front end” refers to the less structured character of the early phase (Khurana, & Rosenthal, 1997). This is mainly due to the high degree of uncertainty (McManus & Hastings, 2005). Uncertainty can arise from a lack of knowledge or a lack of definitions. Whereas the knowledge gap refers to a lack of acquired knowledge to rationally solve a development problem, the definition gap is defined as a lack of definitions and specifications. Therefore, the objective of product development is to continuously minimize uncertainty through an iterative approach (Lindemann & Lorenz, 2008). In accordance with the extended ZHO triple, an iterative approach is required to develop both the system of objectives and the system of objects, and to explicate and document them using product models (Albers et al., 2014). Schröer and Lindemann (2011) apostrophize the importance of visual models (e.g., sketches or wireframes) to explicate conceptual solution ideas in the field of Interaction Design and User Experience. Following Ehrlenspiel (2009), a concept represents a basic proposal for a solution in the context of a technical task. This means that it is not (yet) a complete description of the solution. Rather, it is a description of fundamental aspects of the solution, such as the way in which the intended function is to be realized. According to DIN EN ISO 9241-110, display and operating actions can be subsumed under the term "interaction". Interaction is understood as the "exchange of information between a user and an interactive system". Franz (2014) consequently defines an interaction concept as "the arrangement of operating and display elements in relation to each other as well as the design of the interaction with these elements". Albers & Rapp (2022) emphasize within the explanatory framework of PGE – Product Generation Engineering – that all kinds of product development can be explained as mapping of elements from a reference system into a new product generation. This new product generation is always created by a targeted variation of technical artifacts such as product properties, product functions and physical systems. The Early Phase in the model of PGE – Product Generation Engineering starts with the initiation of a project and ends with the evaluation of a product specification (Albers et al., 2017). The product specification includes information about the technologies and subsystems used, as well as their deployment and new development shares. Therefore, it enables a valid assessment of the product in development with regard to relevant parameters such as manufacturability, required resources, and technical and economic risk (Albers et al., 2017). Research-wise, the Early Phase in the model of PGE – Product Generation Engineering constitutes the methodological-procedural framework of this publication. Heitger (2019) has shown that automotive product development can be described with the model of PGE – Product Generation Engineering. The descriptive research questions are therefore investigated directly in a German OEM as part of a research cooperation.

3 Research Design

OEMs have several levers at their disposal to develop a positive experience for customers and users. However, the design of display and operating concepts for interactions with the interactive product functions of the vehicle is undoubtedly of great importance. The Early Phase of

Product Development therefore plays a key role given the high degree of creative freedom it offers. This is often simultaneously accompanied by a high degree of uncertainty. In order to tackle the outlined issues, the contribution is driven by two research questions:

1. Given the knowledge of the Early Phase of Product Development, which challenges arise in the cross-product line development of display and operating concepts?
2. Which requirements are to be met by a systematic approach for developing cross-product-line display and operating concepts in the early phase in the model of PGE - Product Generation Engineering?

The research design follows the design research methodology framework (DRM) according to Blessing and Chakrabarti (2009). The first research question frames the descriptive problem analysis. A two-step mixed-method research approach was defined to answer this research question. As a first step we conducted a structured literature review on general research potentials in the development practice of display and operating concepts. In addition, a qualitative analysis of the status quo was complemented by a quantitative expert survey with UX experts in the automotive industry. Based on the results of these studies, the second research question aims at deriving requirements for a supporting approach that is designed to close the identified and analysed reseach gap.
The overall objective of this study is to obtain a broad and valid assessment of the current situation from experts working in different companies responsible for a comparable scope of development in the domain of in-vehicle UX. In the first step, based on a structured literature review, general research potentials in the development practice of display and operating concepts were identified. The research method applied was a workshop in the industrial research environment of the main author, who planned the workshop, performed it with the support of a second moderator and followed it up. The 11 participants were divided into two groups and faced with the same research questions. The goal was to discuss the understanding of the term display and operating concept in the considered domain as well as a collection of methodological and procedural best practices and white spots in the early development phase. The results of both the workshop and the structured literature review were leveraged to formulate the hypotheses for the second step of the mixed-methods approach. Due to the higher statistical validity resulting from the broader field of participants, the focus of this publication is on the online survey. The aim of the survey was to gain a broad understanding of current challenges, strategic potentials and success factors in the area of user-centered design and the development of display and operating concepts in the early stage of development processes. A total of 28 items were formulated as hypotheses on the various characteristics. An ordinally scaled six-point Likert scale was used to measure personal preferences. The respondents' level of agreement or disagreement was queried using qualitative levels ranging from "strongly agree", to "strongly disagree". A total of 68 UX experts from several companies in the European automotive industry participated in the survey. Among them, 45 participants completed all 28 hypotheses. Incomplete questionnaires were not included in the evaluation. In line with the DRM Guideline, the results of the questionnaire were used to derive requirements for the approach intended to leverage the identified success factors to overcome the challenges. Blessing and Chakrabarti distinguish between requirements for the applicability, supportability, and contribution to success of research findings. The aim of the underlying research project this paper is part of is a supporting approach for UX developers in the automotive industry. The literature on research in product development already provides extensive discussions on requirements for the applicability of methods. In this publication, we therefore focus on the elicitation of requirements for the supportability and the contribution to success of the targeted approach.

4 Findings

In the following, the results of the survey aiming at answering the first research question are presented in more detail (see 4.1). Subsequently, requirements for the systematic approach to be developed are derived on this basis to answer the second research question (see 4.2).

4.1 Survey results

The majority of the participants (32%) have 5-10 years of work experience. A total of 60% of the participants have at least 5 years of work experience. None of the participants surveyed has less than twelve months of work experience. At 16%, the smallest percentage of subjects has between 1-3 years of work experience. The input of the job title was made by a blank box, so that various titles are subsumed in the category "Other" (23%) (e.g. "Requirement Engineer", "UX Manager" and "UX Coordinator"). In addition to the category "Other", the categories "UX Engineer" and "UX Consultant", also with 23% each, represent the largest occupational groups. With 7%, researchers and scientists represent the smallest share. The hypotheses were grouped into four thematic clusters. The first cluster addresses strategic potentials (cf. Figure 1).

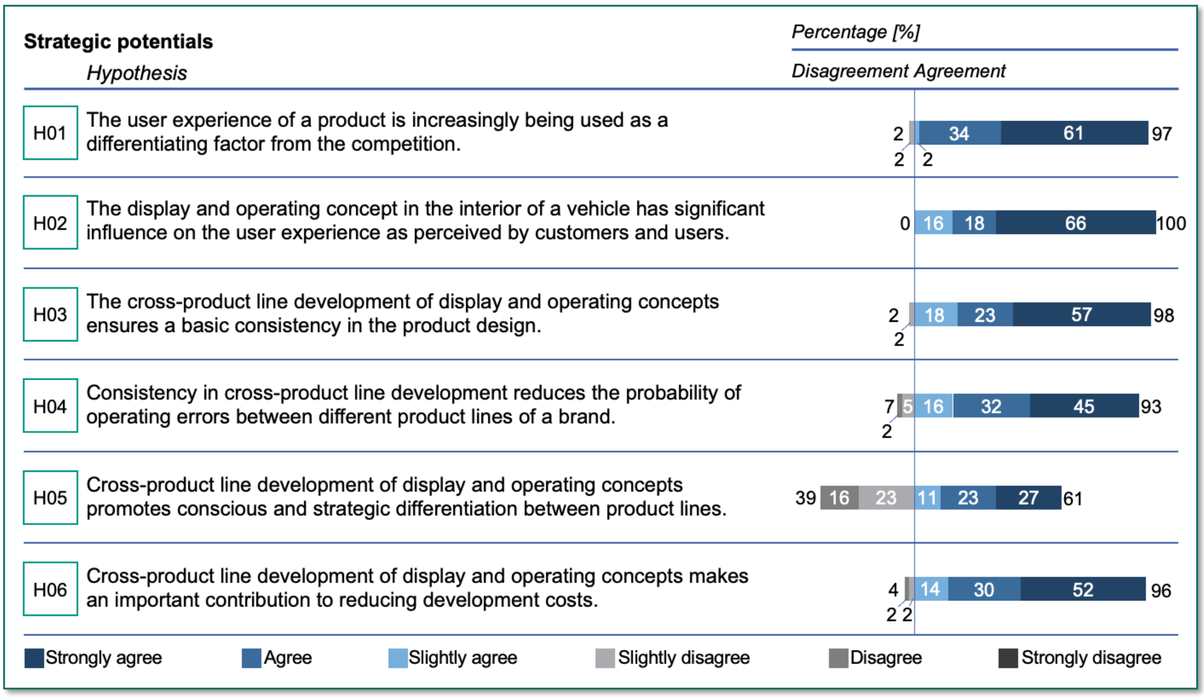

Figure 1: Hypotheses of Cluster 1 "Strategic Potentials"

Fahl et al. (2021) emphasize the potential of cross-product-portfolio development of product functions. In line with these findings, we consider large potential in considering the development of display and operating concepts on a cross-product line level. The results of the conducted online survey confirms this (cf. H01 and H02). 96% of the experts surveyed confirm the potential for reducing development costs (H06). Furthermore, 98% confirm the positive effect on basic consistency in product design within the entire product portfolio (H03). Owners of multiple vehicles from different product lines can thus more easily familiarize themselves with product use, reducing the likelihood of operating errors (H04). In addition, 61% of respondents confirm that a cross-product line development approach promotes conscious and strategic differentiation among distinct product lines of a brand (H05). Numerous approaches to product differentiation can be found in the literature. However, the authors envision cross-product-line development as an opportunity for companies to consciously focus on strategic differentiation in the early phase of product development. This serves as foundation for creating a recognizable brand identity through interaction design and for differentiating the individual product lines according to the individual context of use and the product positioning in the competitive environment. (e.g., differentiation between sports cars and SUVs).

Within the second cluster of hypotheses, the use of reference system elements in the context of developing display and operating concepts was investigated cf. Figure 1). A total of 96% of the respondents confirm that the analysis of existing reference products contributes significantly to the elicitation of requirements for display and operating concepts (H07). A total of 86% also see the potential to reduce market uncertainties with regard to unclear UX and usability requirements of customers and users (H09). Referring to the characteristics of the early development phases, this is particularly relevant. Dealing with uncertainty is identified as a core challenge in the literature. Thereby, the analysis extends beyond existing products in the sense of physical systems. In particular, if the system of objectives of the analyzed systems can be reconstructed, developers can draw on comprehensive information. Further 93% agree with the hypothesis, according to which the use of reference products improves the understanding of the stakeholders for developed display and operating concepts. For example, if developers transfer interaction metaphors from products familiar to the customer or user into their reference system, this can improve the understanding of the display and operating concept. Furthermore, this phenomenon can facilitate internal communication and decision-making in the development process. It should be noted that relevant reference products for the examined domain can increasingly be found outside the automotive industry. In total, 93% of the respondents confirm this (H08). The authors attribute this result to the fact that products from the consumer goods industry, for instance, have become constant companions for customers and users in their daily lives.

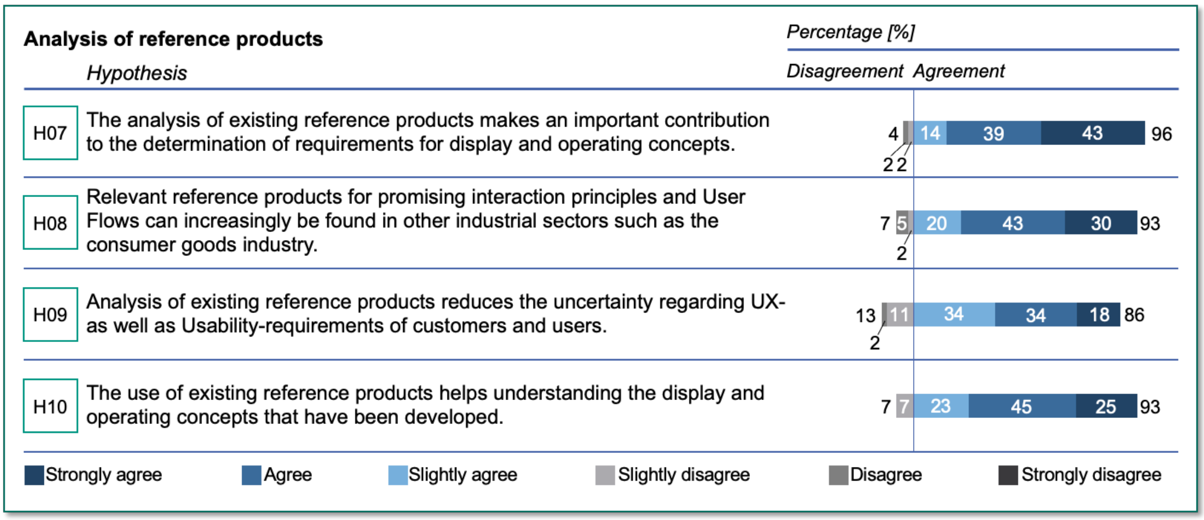

Figure 1: Hypotheses of Cluster 2 “Analysis of Reference Products”

Following on from the workshop conducted in the first step, central hypotheses were formulated on the conceptual term as well as the process requirements for creating display and operating concepts (cf. Figure 2). The experts differ on the added value of a list of requirements as concept documentation (H11). 55% of the respondents confirm that a display and operating concept can be clearly modeled using a requirements list. Accordingly, 45% reject this hypothesis. The distribution of preferences towards the less absolute positions is remarkable. The absolute positions ("strongly agree" and "strongly disagree") have comparatively low scores. This suggests that the role of requirements and corresponding requirements-based specifications is controversial among UX experts. All of the experts surveyed consider a visual representation of the concept to be essential for understanding (H12). Models established in literature and practice are, for example, user journey maps, use case diagrams, or sketches of user interfaces depicting the flow of operation and display. Interaction with graphical user interfaces is often visualized by so-called wireframes. A standardized model with a uniform ontology that can be used for all cases - comparable to Matlab or Simulink models in the field of modeling mechatronic systems - has not yet emerged. This leads to the conclusion that purely requirements-based documentation, such as in a specification sheet, is not sufficient. In order to achieve the goal of a positive user experience with the display and operating concept, concrete product objectives are required as an input variable according to 94% of the expert assessments (H13). According to 98% of the experts, prioritizing partial objectives is of central importance at the start of development (H14). In addition, 93% of the experts believe it is important to consider product attributes for usability when developing display and operating concepts (H15). The experts are uncertain about the level of detail of technical specifications for the concept. 55% of the experts confirm that these should already contain concrete technical solution ideas for implementing the concept as well as variations in HW and SW (H16). Due to the controversial sentiment, this is to be analyzed in more detail in the further course of the research project. In the state of the research, the Early Phase of Product Development was characterized as highly uncertain. A proportion of 82% of the experts confirmed that the targeted development of display and operating concepts in the Early Phase is more difficult due to uncertainty – in particular due to the latency of requirements (H17). 93% confirm the often neglected involvement of users in the elicitation of requirements for display and operating concepts within the Early Phase as a reason (H18).

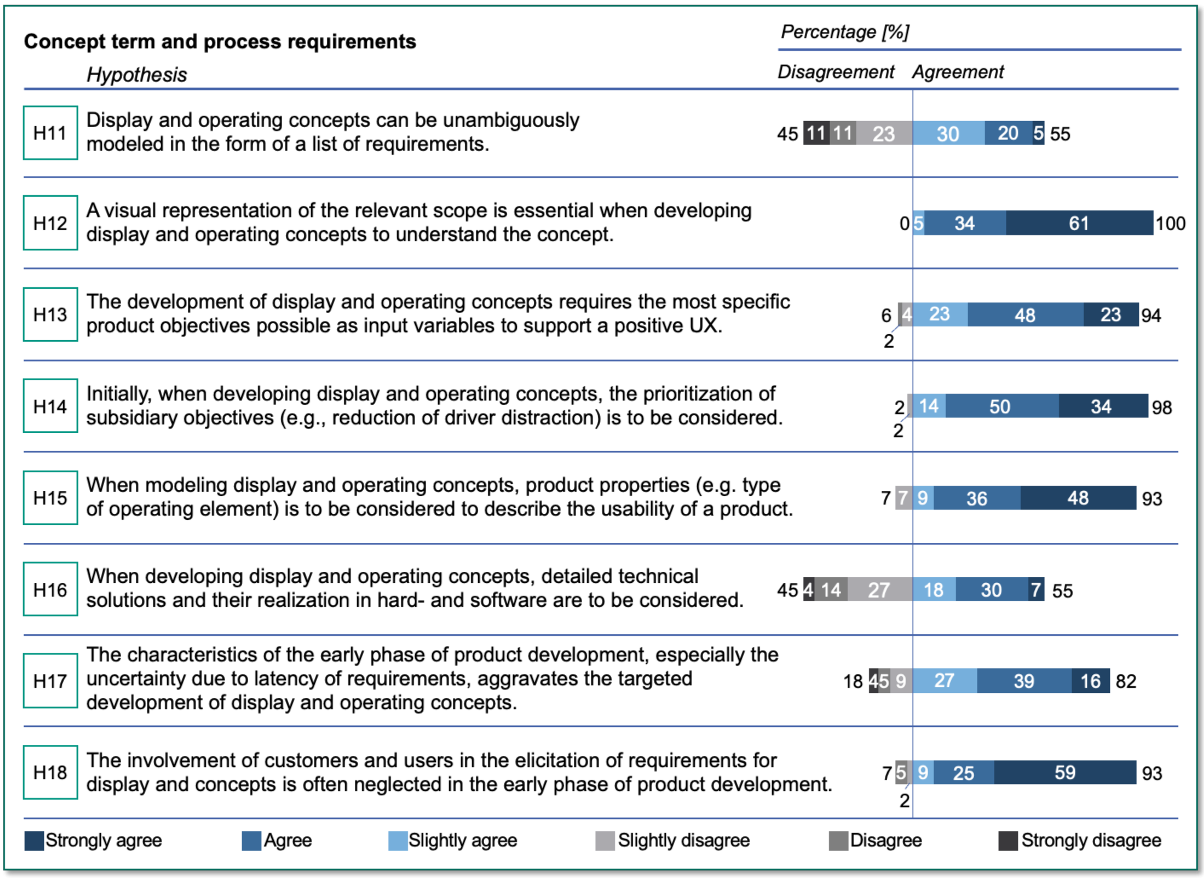

Figure 2: Hypotheses of Cluster 3 "Concept Term and Process Requirements"

The fourth cluster focuses on potential for methodical support in the development of display and operating concepts (cf. Figure 3). The main author of this contribution observed in the course of his work as a collaborating researcher in the industrial research environment that the mentioned direct involvement of customers and users is only possible to a very limited extent.

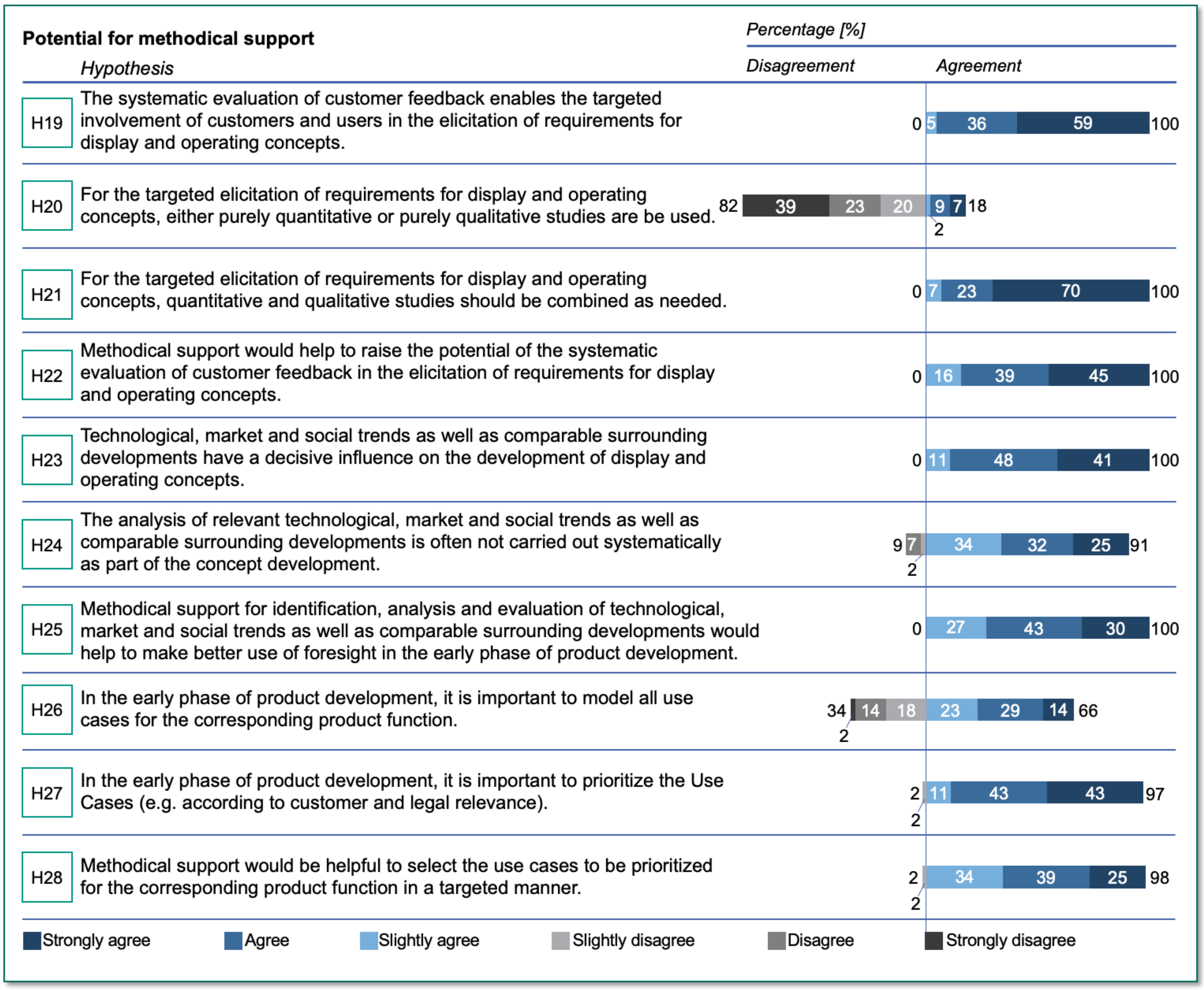

Figure 3: Hypotheses of Cluster 4 "Potential for Methodical Support"

The main reason are company requirements for secrecy in the Early Phase. Consequently, customers and users have to be involved indirectly in the development. The experts unanimously confirm that the systematic evaluation of customer feedback – e.g., via market studies or the collection of usage data – can be a remedy (H19). Furthermore, the survey confirmed, with 100% agreement in each case, that qualitative and quantitative studies for requirements elicitation should be appropriately combined (H20, H21) and that methodological support would be helpful in raising existing potential in the early phase (H22). Furthermore, all the experts surveyed share the view that technological, market and social trends as well as comparable environmental developments have a decisive influence on the development of display and operating concepts (H23). Nevertheless, 91% agree that analysis in practice is often not carried out in a targeted manner (H24). The experts unanimously confirm the potential for methodological support in order to make better use of future knowledge for early-stage development (H25). Engineering activities in the early phase require a clear focus due to the inherent uncertainty. Furthermore, different papers emphasize that the key is to quickly create an early concept prototype that is subsequently tested and then refined. While 66% confirm the need to model all use cases in the early phase (H26), at the same time 97% of respondents believe that prioritization (e.g., by user, customer and regulatory relevance) is necessary in the early phase (H27). At this point, the survey does not provide a clear result. Further analyses of this aspect are to be carried out in the course of the project. The concluding hypothesis that methodological support would help to select the use cases to be prioritized in a targeted manner (H28) receives broad support from 98%. The authors conclude that it is not possible to consider all use cases in the Early Phase.

On the one hand, a concept responsible often has to cover a very broad area of responsibilities and thus simply does not have the capacity to incorporate every use case. On the other hand, this is also not efficient in some cases. For example, certain modeled concept elements can serve as a reference for similar use cases, from which the implementing departments can derive the corresponding elements. Another aspect in relation to the phenomenon of market uncertainty is the probability that not all use cases are known at all in the early phase. This is a major challenge, especially if there is a high share of new developments. For instance, for highly automated driving, the detailed customer requirements have not yet been sufficiently researched. Nevertheless, UX experts can make uncertainty manageable by using reference system elements. When the primary driving task is eliminated, it is possible to initially derive user requirements through comparison with the user journey of train and airplane passengers.
Based on the survey results, we formulated four qualitative key success factors for UX experts in the automotive industry. These were then utilized to derive requirements for a supportive systematic approach for the development of cross-product line display and operating concepts in the early phase of PGE – Product Generation Engineering.

4.2 Deriving requirements for the systematic approach to be developed

The DRM framework provides researchers with three types of evaluation for the assessment of findings: 1) the applicability evaluation assesses the solution developed on the basis of its applicability in the intended practical environment, 2) the support evaluation examines the solution in terms of its functionality, 3) the success evaluation assesses the solution on the basis of its added value in relation to the specified requirements (Blessing & Chakrabarti, 2009). Focus of this publication is on the support capability as well as the success contribution of the systematic approach to be developed. In the further course of research, applicability requirements will be determined on the basis of literature as well as observational studies and expert interviews. First of all, we formulated four qualitative success factors for the addressed target group of UX experts in the early phase of automotive product development. These are deduced from the answers given in the survey and were formulated from the experts' point of view. The success factors consequently result in the requirements for the support capability and the success contribution of the approach. Based on the findings, five requirements for the support capability (A) and two requirements for the success contribution (B) were derived (cf. Figure 4). At this point, it should be noted that the targeted approach is to be seen as research-in-progress. Consequently, the derived requirements represent a first draft based on the workshop and the survey. According to the evaluation of hypotheses H23-H25, the experts interviewed emphasize the need to support the analysis and evaluation of trends and comparable environmental developments (A1). The requirement for support for the case-specific combination and evaluation of qualitative and quantitative studies (A2) is derived from the results for H19-H25. Furthermore, H13-H15 emphasize the importance of support for the synthesis and concretization of UX-related product objectives and requirements (A3). Another crucial element is the integration of customers and users into the development practice in the early phase (cf. H18, H19). Direct involvement, e.g., in the form of A/B testing with interactive physical prototypes, is not promisingly possible due to challenges related to confidentiality. Consequently, the systematic approach must provide a way to involve customers and users in concept development nonetheless through the use of user-centered methods (A4). In line with Section 2.2, H7-H10 confirm the potential of using a reference system and reference products in concept development. Consequently, it is necessary to support this methodically within the framework of the aspired systematic approach (A5). Based on the theory of usability and user experience, display and operating concepts are perceived very subjectively. Product attributes such as longitudinal dynamics and acceleration can be easily defined by quantitative target values. They are therefore easier to objectify than UX and usability attributes. The literature as well as the underlying industrial research environment of the main author do not currently provide generally accepted metrics for this. Furthermore, Literature characterizes the early phase as highly uncertain. Hypothesis H17 confirms that this circumstance makes the development of display and operating concepts significantly more difficult. This results in the success requirement B1, according to which the market uncertainties caused by unclear requirements of customers and users are to be reduced with the help of the approach. Following on from this, the previous study confirms that although future forecasting in the form of trend analysis is highly relevant to the development of display and operating concepts, in practice it is often not carried out in a targeted manner. This often leads to the fact that an analysis takes place, however, this is not linked with the concept development. Consequently, the acquired knowledge about future developments is not fully utilized. Complementary observations in the industrial research environment of this publication confirm this. This suggests that the approach requires linking the analysis of trends with concept development in the early development phase (B2).

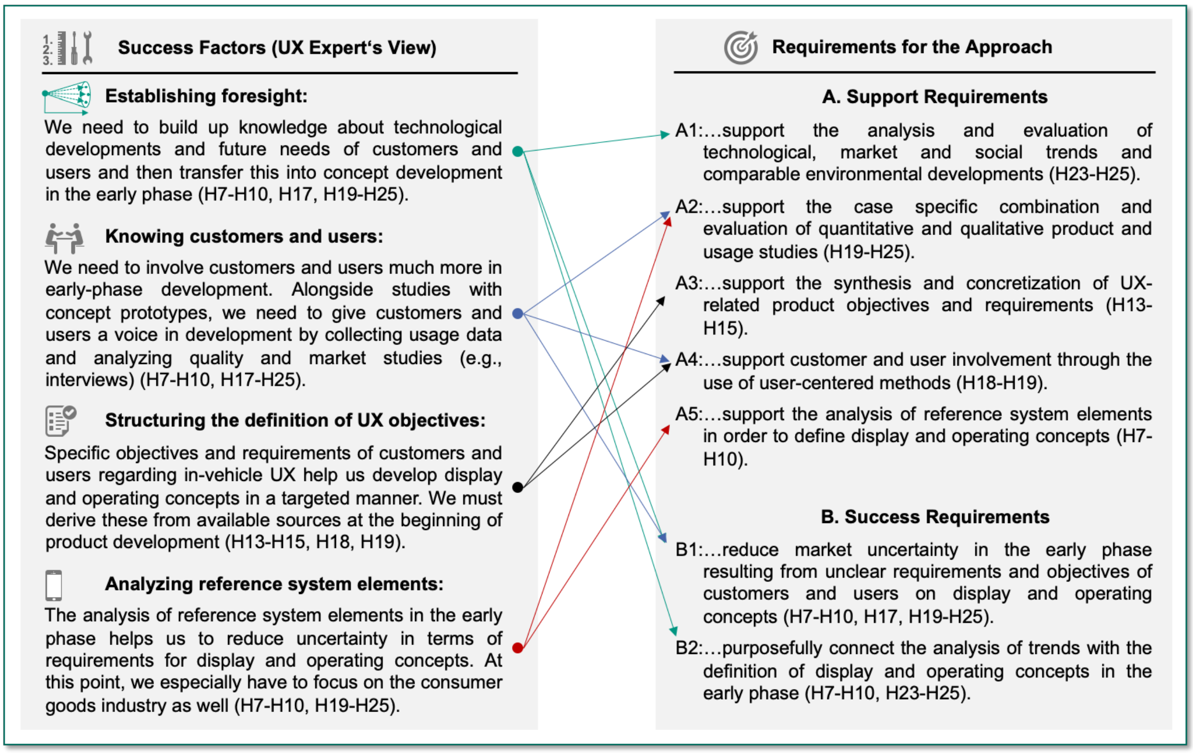

Figure 4: Qualitative Success Factors and Requirements for the intended Approach

5 Conclusion and Outlook

The overall research objective of this publication is the elicitation of requirements for a systematic approach supporting product developers in the Early Phase in developing display and operating concepts and thereby reducing market uncertainties due to unclear objectives and requirements from customers and users. Our focus is on automotive vehicle design and engineering. The underlying research project is part of a cooperation with a German OEM. In the course of a two-step mixed-methods analysis, challenges and success factors within automotive product development were identified by means of a workshop and a consecutive online survey. The results were utilized to derive requirements for the intended approach. Likewise, the study also revealed the need for further research. Hypotheses H3-H6 confirmed the potential of cross-product line development of display and operating concepts. This requires analyzing and describing the development situations that occur in the Early Phase in a supplementary study. The

UX experts also confirmed the need for a methodology to integrate quantitative and qualitative data regarding usage patterns of customers and users. Significant hurdles are encountered in development practice, especially when it comes to collecting usage data from field vehicles. From a concept development perspective, the goal is to use available knowledge from such studies as easily and regularly as possible for development activities. The survey already provides unequivocal results on numerous issues. Nevertheless, individual hypotheses need to be examined more closely in a further survey among experts. The results of hypotheses H11-H12 show that the experts differ on the importance of requirements and requirements-based specifications in the development of display and operating concepts. The same applies to the results of hypotheses H26-H27 regarding the need to prioritize use cases in the Early Phase. Even though the experts largely agreed on the integration of data, the authors also see a need for further research in this area. In particular with regard to the potential and limitations of such information as well as best practices for seamless integration into the product development process, further studies need to be conducted. Semi-structured follow-up interviews with selected experts from the test pool have already been planned for further investigation in order to support a valid interpretation of the results. Furthermore, it is essential to assign metrics to the success requirements of the systematic approach to evaluate the influence of the approach on the perceived market uncertainty in the Early Phase.

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