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Optimisation Approach for the Convergence Process of Design and Technology in Automotive Development

Florian Reichelt, Daniel Holder, and Thomas Maier

Institute for Engineering Design and Industrial Design, Department of Industrial Design Engineering, University of Stuttgart, 70569 Stuttgart, Germany

ABSTRACT

Technical product development (PD) is becoming increasingly complex. New adaptations have to be carried out constantly in order to meet the process-related, but also product-related challenges. In order to be able to effectively optimise a development process, a precise understanding of the process, i.e. on the process steps and correlations, is necessary. The fundamental decisions during automotive development are made in the early phase as part of the Design-Technology Convergence process (DTC). For this reason, the convergence process is of great importance for automotive development and yet there is very little valid knowledge about it. In addition to the ambiguity of the cause-effect relationships in this phase, no specific approaches exist to initiate necessary changes in a holistic way, taking into account the prevailing characteristics in this important phase, in order to make PD fit for the current challenges. Therefore, the aim of this paper is to elaborate approaches for optimising PD in the early phases, especially DTC from everyday practical experiences.

Keywords: Management strategies, Design strategy, Design method, Human-centered design, Design-technology convergence

INTRODUCTION

The automotive industry is currently facing a variety of new challenges. These global core challenges can be classified in terms of their process-related and product-oriented impacts. As far as process is concerned, Bennett & Lemoine (2014) define the challenges as an increase in volatility, uncertainty, complexity and ambiguity (VUCA). According to a study conducted by consulting firm PriceWaterhouseCoopers, challenges related to the technological development of vehicles are characterised as electrified, autonomous, shared, connected, yearly updated (eascy) (Kuhnert et al., 2017).

In a previous study, Reichelt et al. (2021) found that these challenges also apply to the early stages of vehicle development, particularly the convergence between design and technology (DTC). In addition to these external challenges, internal challenges were also identified to be considered in the necessary adaptation of DTC. These challenges were based on a systematic literature review and expert interviews with project leaders and managers from practice. As a result of this work, an approach was developed how the early

phases of the design development can be mastered with regard to the current challenges by means of conscious and situation-adapted process modelling.

In our current contribution, we expand on the interviews as an immediate link. We extend the interviews to practitioners from the DTC in order to gain specific insights into the processes and thus enable targeted optimisation, which Cross (2007) argues is a key element for the efficient and effective transformation of processes. Therefore, in the following, we present the results from these interviews with designers, ergonomists and engineers, whose knowledge from their everyday work in the early phases was thus collected, in order to obtain a more detailed picture of the process, as well as the needs and optimisation requirements. Based on the results, we derive not only current challenges and optimisation potential for improvements in the DTC, but also specific approaches for implementing continuous improvement of the DTC. Compared to well-known approaches, these approaches focus on the specific characteristics of DTC. In particular, the prevailing conflicting goals are comprehensively addressed by the different approaches so that sustainable change can be made possible.

METHODS

As already mentioned, the research conducted by Reichelt et al. (2021) forms the essential basis for this paper. In order to complete the picture of challenges and requirements, specific input from the areas of DTC was required. Since this area is one of the most important in the automotive industry, this branch was used as a guiding example. The experts were professionals from the automotive industry who contributed their experience of daily work in the development of design, ergonomics and/or technologies in the early phases of vehicle development.

The interviews took place between July and November 2021. Experts were chosen who offered at least one of the required areas of expertise as a result of their education/professional training or their occupation. In total 21 workshops were held. All the experts could be assigned to one of the three focal points of the study (design – ergonomics – technological development). Due to incomplete data only 19 datasets were suitable for evaluation.

Each interview took the form of an individual meeting in Microsoft Teams. The questionnaire for the interview was completed with each expert using the screen-sharing functionality. Notes of the expert's statements were made by the interviewer, so the expert was able to follow what was being written directly. All interviews were hosted by the same investigator with compulsory guidelines to ensure they were all staged in a consistent, comparable form.

The interview was a structured interview (Döring et al., 2016) during which set open-ended and closed-ended questions were asked. A five-point Likert scale was used for the closed questions ranging from 'definitely' to 'absolutely not'. At first demographic data and appraising personal expertise with regard to vehicle development or, more specifically, the areas of design, ergonomics and technological development were recorded. The experts were then asked questions about their knowledge and understanding of project management. With regard to evolution of the design process, particularly in

terms of design-technology convergence (DTC), targeted questions were put to the interviewees to derive potential for optimisation.

Four open-ended questions were asked with the ultimate aim of deriving this potential for optimisation from the answers given:

Q1: What impact do the industry's core challenges have on the design process?

Q2: What will definitely change in the design process over the coming years?

Q3: Where do you see a need for optimisation in the design process?

Q4: What need for optimisation do you see in the design-technology convergence?

Evaluation of the interview questionnaires was purely descriptive (Kosfeld et al., 2016). The results of the closed-ended questions are depicted by means of frequency distributions. The answers to the open-ended questions were analysed using the qualitative content analysis method of Mayring (2020) and are also depicted in the form of frequency distributions. Four of the 19 experts were female (21%). All experts had at least five years of professional experience in their specialist area.

In order to realize the identified potential, approaches from practice and science were investigated as to how optimisations can be carried out in the DTC. Since no approaches could be identified that were specifically tailored to the unique circumstances of DTC, we defined a holistic approach, which is designed for the purposes of continuous improvement of DTC.

INTERVIEW RESULTS

In order to identify the challenges for the early phases of vehicle development specifically, the experts were asked to name the challenges they encounter in their day-to-day work, with open answer options (Q1). Central challenges in the design process were identified as: *more specifications; boundary conditions and requirements; the need for higher process speed; the increased focusing on user experience (UX); greater uncertainties at the start of a project* and *the need for new product architectures and structures*.

In order to respond to these new challenges, changes in the design process are unavoidable. To identify significant changes in the design process over the next few years, the experts were again presented with an open-ended question (Q2). The key changes the experts envisage over the next few years are: *a shortening of development cycles; greater use of digital tools; presentation / development methods becoming more dynamic; increasing digitalisation of the product* (the proportions of software and hardware will alter).

The results and other aspects mentioned by the experts regarding the challenges and changes are shown in Figure 1.

As well as giving their assessments on the challenges and changes in the design process, the experts were also asked about the potential for optimisation in the design process. They were asked to give their thoughts on the available potential both in the design process in general and specifically

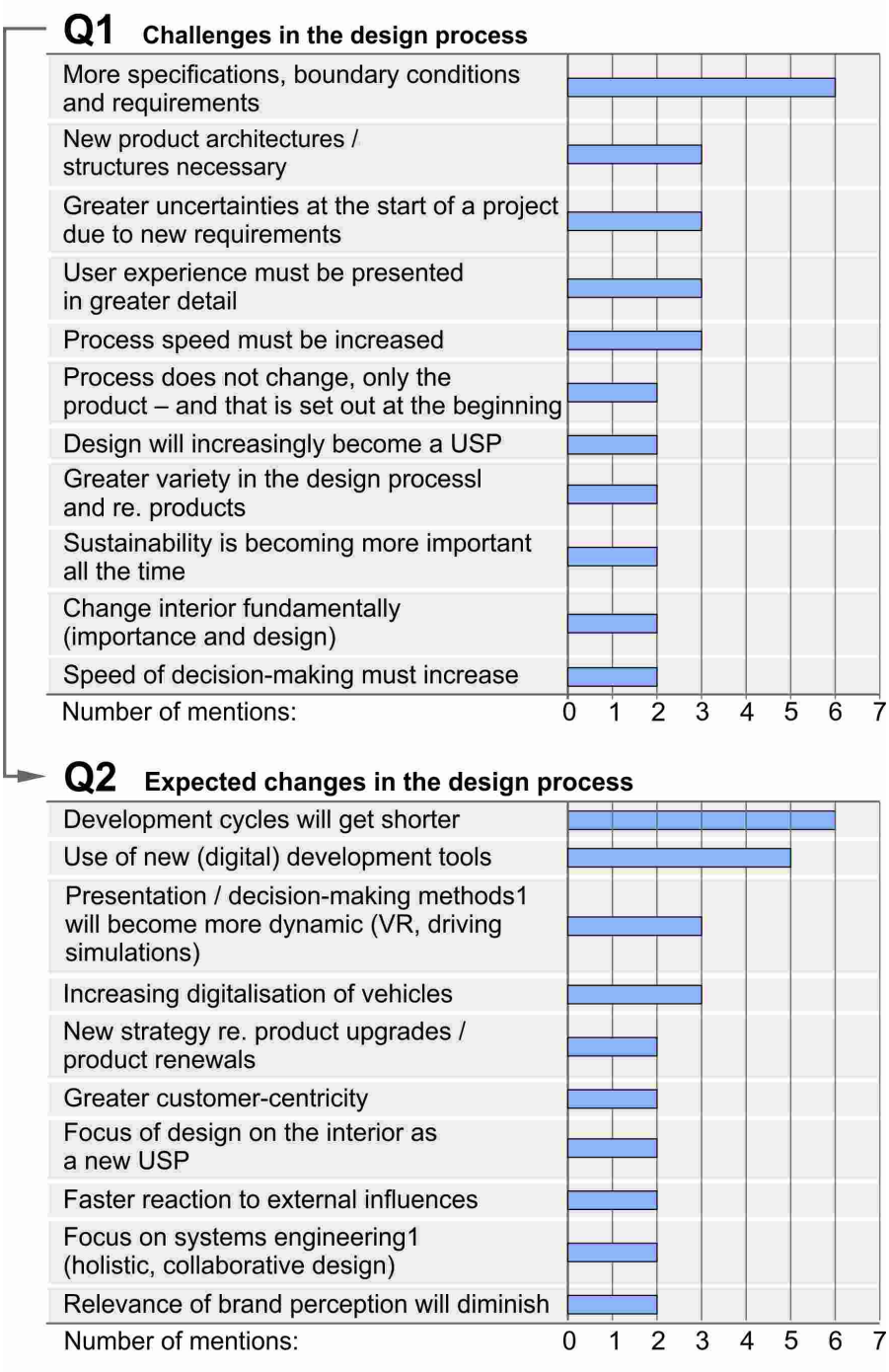

Figure 1: Key challenges in the design process (above) and related changes (below).

in terms of design-technology convergence. The questions were again asked openly. The results are shown in Figure 2.

For the design process, the following were identified as key areas of potential: b*etter cooperation between the departments (DTC); closer contact*

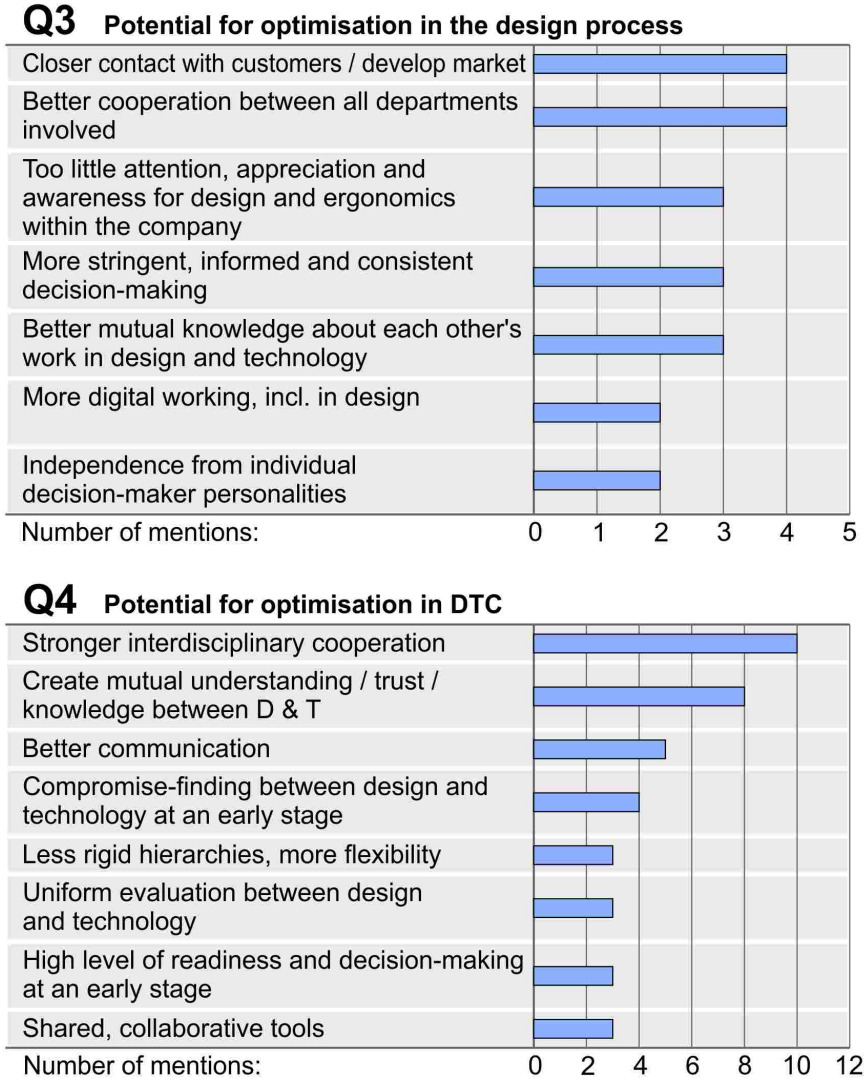

Figure 2: Results of the open-ended questions on the potential for optimisation in the design process in general (above) and in design-technology convergence (below).

with customers; greater appreciation for and awareness of design and ergonomics within the company; better and more transparent decision-making and *the improvement of mutual knowledge, specifically between design and engineering*.

In terms of the potential regarding DTC, the following aspects were identified as important areas of potential for optimisation: *greater interdisciplinary cooperation in the teams; creating mutual knowledge / trust with the other disciplines; better communication between the departments* and *starting DTC at an early stage*.

With regard to the prevailing study, there is on the one site a certain overlap between the statements found with experts of project management

(Reichelt et al., 2021) and the results above: the need for a *closer contact with customers*, *greater interdisciplinary cooperation in the teams; creating mutual knowledge / trust with the other disciplines; better and more transparent decision-making; better communication between the departments* and *starting DTC at an early stage* are similar high ranked potential for the DTC in the findings of Reichelt et al. (2021). On the other side with the specific insights of practitioners in the DTC detailed information and requirements could be derived.

APPROACH FOR OPTIMISING DESIGN TECHNOLOGY CONVERGENCE

In order to be able to adequately address the identified challenges and potential, the results of a systematic literature research regarding optimisation approaches for continuous improvement in product development are presented below. Since there are no suitable approaches for DTC that cover the entire range of challenges identified, new approaches for optimising DTC are then derived. Finally, these are compared with the identified challenges and potentials.

For the operationalisation of continuous improvement of development processes, there are mainly theoretical-abstract models in the literature: The most common approach is the PDCA cycle according to Deming (1986) (Lodgaard & Aasland, 2011). This approach is considered universal for the change of processes of any kind, but has no concrete implementation strategies or procedures. Especially for technical product development there are approaches such as Lean Development (cf. Dombrowski, 2015) and Value Management (cf. DIN EN 12973). These provide principles on how processes (Lean Development) or products (Value Management) can be improved. Implementation possibilities are described, but these are mainly on a structural or procedure-based level and thus only focus on a certain part of product development. Both approaches can therefore only be applied to parts of the applicable requirements of the DTC; for example, the further development of the developers and the task-specific tool and method use remain unaddressed. For a more practical implementation of improvements, there are approaches that can have an influence, for example, through modelling, simulation and adaptation of processes (cf. Wynn, 2007) or knowledge management (cf. Laukemann, 2021). However, these approaches have in common that they focus on the general development process, but not on the early phases of product development.

Since there are special circumstances in these early phases, especially due to the strong interdisciplinarity, the previous approaches are not suitable for use in DTC.

Based on the assessment of potential shown above, clusters can be synthesised looking at how certain challenges and changes (see Q1 & Q2) can be addressed and how the potential identified in the design process overall and DTC specifically (see Q3 & Q4) can be utilised. In principle, these can be divided into *method-based, structural / process-based, tools-based* and *skills-based* approaches. Figure 3 shows the different approaches for optimising the design processes.

Figure 3: Visualisation of the approaches.

The *method-based approach* focuses on the adapted and therefore targeted use of methods in project management. This allows the procedure for handling the relevant activities of the respective development phases to be aligned efficiently to the development situation at hand. This enables the developers to carry out the required work on an operative level more effectively and efficiently. For example, the Agile Systems Approach – ASD developed by Albers et al. (2019) or the reflection and modelling approach using a Method-DNA based on Reichelt et al. (2023) can be mentioned as implementation concepts.

With the *structural / process-based approach*, solutions for making work steps and methods more flexible are created by adapting the project structures and the sub-processes at module or component level. For example, flexible (re)scheduling of intermediate milestones or deliberately carrying out activities in parallel can allow short-term acceleration and therefore a suitable response to external influencing factors. The mentioned approach by Reichelt et al. (2021) as a situation-adapted process modelling or the fundamentally new structure of a technology-driven development process described by Reichelt et al. (2022) can be mentioned as possible concepts.

The further development of tools and the use of new tools such as VR / AR (cf. Oberhofer, 2022) or rapid prototyping (cf. Hein, 2021) enables *tools-based* influence over development activities.

The *skills-based approach* takes the form of training and further education for project employees, e.g. on new methods, processes and interface activities. Added to which, training in soft skills and tools can also influence the development process.

By implementing the four approaches, the challenges, changes and areas of potential identified by the experts can be addressed in different ways. In Table 1, the aforementioned comments on questions Q1-Q4 are listed and paired with the approaches which can be used to turn this potential into results.

Parallel application of approaches therefore allows the challenges to be countered through *optimisation of decision-making and a larger selection of design variants*. The expected changes in the process – *focusing on systems engineering* and *new presentation and decision-making methods* – can be implemented. In terms of potential for optimisation in general, the main area of focus is *greater cooperation between all areas*. Looking at DTC

Table 1. Overview of the optimisation opportunities in the application of the four approaches.

	Method-based approach	Structural/process-based approach	Tool-based approach	Skills-based approach	
Challenges (Q1)					
Optimisation of decision-making	X	X	X	X	4
Larger selection of design variants	X	X	X		3
Reduction of uncertainties, esp. in the early stage	X			X	2
Better focusing on user experience (UX)	X			X	2
Switch in importance from exterior to interior		X		X	2
Consideration of stricter specifications, boundary conditions		X			1
Development of new product architectures and structures		X			1
Increasing process speed		X			1
Developing design into a USP		X			1
Introduction of sustainability as a development basis				X	1
Changes (Q2)					
Focusing on systems engineering	X	X	X	X	4
New presentation and decision-making methods	X		X	X	3
Shortening development cycles	X	X			2
Faster reaction to external influences	X	X			2
Use of new, digital development tools			X	X	2
Expanding greater customer centricity	X				1
Support with digitalisation of the vehicles		X			1
Taking into account new product strategies		X			1
Promoting interior design as a new USP		X			1
Potential in the overall design process (Q3)					
Stronger cooperation between all areas	X		X	X	3
Closer contact with customers and the market	X			X	2
Greater attention to, appreciation and awareness of design and ergonomics within the company		X		X	2
Better mutual knowledge of each other's work		X		X	2
Better decision-making in the development process			X	X	2
Better objectification of decision-making (independent of subjective influencing factors)			X	X	2
More stringent, informed and consistent decision-making	X				1
More digital working, incl. in styling			X		1
Potential in DTC (Q4)					
Stronger interdisciplinary cooperation	X	X	X	X	4
Compromise-finding and decision-making at an early stage	X	X	X	X	4
Better communication	X		X	X	3
Uniform evaluation between design and technology	X		X	X	3
High level of readiness at an early stage	X	X	X		3
Improvement of mutual understanding and knowledge		X			1
Less rigid hierarchies		X			1
Shared, collaborative tools			X		1

specifically, most potential can be found in the parallel application of various optimisation approaches: *stronger interdisciplinary cooperation, early compromise-finding and decision-making, better communication, consistent evaluation between design and technology,* and a *high level of readiness at an early stage.*

CONCLUSION AND OUTLOOK

Based on our investigations, we were able to generate a valid image of real-life practice in the early phases of the automotive development process. On the basis of this image, we identified both the current challenges as well as the potential that ultimately describe the need for optimisation of the DTC. Thus, on the other hand, specific approaches could be derived as to how an optimisation of the DTC can be accomplished so that the identified potential can be effectively raised. Furthermore, the results also serve as requirements for the targeted implementation of changes in the DTC. Ultimately, the combined application of the various approaches results in a holistic strategy for the implementation of optimisations in the early phases of PD in the automotive industry. This strategy is characterised by the fact that it addresses the different design levels and brings together a method-based, process-based, tool-based and skills-based approach. The focus going forward is primarily on the implementation of methodological, process-based/structural and tool-based approaches. The skills-based approach is of great relevance for initial and further training in design and therefore also for university teaching and employee development in companies.

The approaches presented here provide initial indications for optimising the cooperation between industrial and engineering design. For implementing these approaches, the influence of the approaches on one another, resulting through a certain lack of clarity, must be taken into account. For example, the use of methods is directly dependent on the use of tools. In particular, the skills-based approach depends directly on the individual skills of the developers, which can lead to very different initial scenarios depending on the company.

Therefore, we will focus on future work specifically on the method-based and process-based/structural approach. Here the influences for project management to monitor and control are the highest. Ultimately, this will be the first step towards adapting consistent processes in the DTC to meet the current challenges.

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