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IMPROVEMENT OPPORTUNITIES FOR THE COLLABORATION OF DESIGN AND SIMULATION DEPARTMENTS - AN INTERVIEW STUDY

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Abstract

As mechanical simulations of products play an increasingly important role in design processes, improving the collaboration of design and simulation departments has come into focus. In order to identify barriers and according improvement measures, semi-structured expert interviews were conducted with participants from 16 companies of different sizes and industry sectors. Building on three basic structures for the integration of simulation departments, improvement opportunities were derived consisting of an identified barrier and an associated improvement measure for each of the 20 barriers.

Keywords: communication, collaborative design, design process, mechanical simulations, interview study

1. Introduction

With the increasing complexity of products as well as the competitive necessity of short development cycles, product simulations have gained increasing attention (Frank et al., 2007). In order to avoid expensive destructive tests and prototypes, simulations like FEM and CFD are used to gain knowledge of the behaviour of a product in early stages of the product development process (Kreimeyer et al., 2005; Sippel, 2009). This leads to an increasing number as well as an increasing complexity of simulations (Reicheneder, 2015; Schlenkrich, 2015).

To improve the resulting integration of simulations into product development processes, a lot of scientific as well as company-driven research has been conducted on tools and data (Motte et al., 2014). Far less has been done on the collaboration and communication within and across engineering departments that results from the increasing application of simulations in product development.

This paper focuses on these aspects of engineering management and analyses the communication channels and collaboration structures in several German engineering companies.

The main goal of this empirical study is to identify typical barriers between design and simulation departments and measures how to overcome them.

2. State of the art and related work

As Herfeld et al. (2005) have shown, most of the research on the integration of simulations in product development have focused on tools and data. This trend has continued in recent years as shown in Schweigert et al. (2015). As a consequence, there is great potential for the efficiency and effectiveness of engineering design processes lying in research on communication and collaboration of people in processes (Kreimeyer et al., 2006).

Similar to Maier (2007), *Communication* in this work refers to interaction between people and the transmission of information in a social and organizational context. It can be seen as part of *Collaboration*, which is defined as the act of working together in a project or any other sort of goal-oriented activity. This refers to the "3C Collaboration Model" Fuks et al. (2008), in which collaboration includes communication, coordination, and cooperation.

The background of the interview study presented in this paper is a questionnaire-based online survey presented in (Schweigert et al., 2017b). It showed that the main barriers in the collaboration of design and simulation departments are in the field of interpersonal relations and communication. A majority of the participants saw a need for efficiency improvements, especially in the area of communication across departments. Herfeld et al. (2006) have laid the foundations for this work with the definition of five dimension of the integration of Computer Aided Engineering (CAE) into Computer Aided Design (CAD): product, people, tools, data, and processes.

Similar online surveys like the one presented in (Schweigert et al., 2017b), which this paper bases on, have been conducted by Eriksson et al. (2014) and Kreimeyer et al. (2005). While Eriksson et al. (2014) try "to bring about a deeper understanding of the interactions between the engineering design and the design analysis activities" with special emphasis on management and communication of computer-based design analysis results, the focus of this survey and the interviews following it was to identify barriers between the departments. The survey of Kreimeyer et al. (2005) was the role model for the follow-up survey in (Schweigert et al., 2017b).

King et al. (2003) conducted research with five companies from different industries with "the objective of determining how CAE analysis is used for product development". Their resulting *Good Practice Model* builds on the pillars *PDP Organisation*, *Hardware, Software*, and *Support & Development*. In comparison, the emphasis on communication and collaboration is lower than found reasonable by the authors of this paper as also shown in results below. The interviews presented in Petersson et al. (2015) focus on the implementation of a single measure - namely Template-Based Design Analysis (TBDA) rather than giving a more general overview of the integration of simulations in product development and resulting barriers.

3. Methodology

3.1. Scientific approach

The method of choice for the information acquisition in this paper were expert interviews. Out of the 73 participants of the online survey presented in (Schweigert et al., 2017b), a total number of 16 experts could be acquired to be interviewed as a part of this paper.

Each of them fulfilled the criteria for an expert as defined by e.g. by Liebold and Trinczek (2009) or Niederberger and Wassermann (2015), as each of them had detailed and specialized knowledge in a certain, clearly defined domain - the integration of design and simulation in this case.

Interview techniques as described in (Kaiser, 2014) were used to prepare and conduct the interviews, namely semi-structured interviews with a special emphasis on proofing the status of co-expert for the person conduction the interviews to avoid the risk of the interviewee getting lost in platitudes or generalizations. The main research questions guiding the interviews were:

1. *What barriers in the collaboration of design and simulation departments in German companies can be identified by expert interviews?*
2. *Which opportunities of improvement for the collaboration of design and simulation teams can be detected from the findings of the interviews?*

3.2. Data acquisition

The overall process of the interview study lasted for six months between October 2016 and March 2017. 16 experts from 15 companies within the German engineering industry took part in the study. Another three interviews that had been already conducted before could be used for the analysis. Table 1 lists the companies that took part in the study.

Table 1. Companies that participated in the interview study

#	Company Description	#	Company Description
1	Fluid Systems Manufacturer	9	Leading Braking Systems Manufacturer
2	Large Automotive OEM	10	Mid-Tier Diesel Engines Manufacturer
3	Customized Robotics Manufacturer	11	Hydraulic Lifting Device SME
4	Leading Household Appliances Manufacturer	12	Leading Automotive Supplier
5	Drive Technology SME	13	High Frequency Technology Manufacturer
6	Automotive Supplier SME	14	Leading Nuclear Technology Supplier
7	Mid-Tier Automotive Supplier	15	Gearing Technology SME
8	Automotive Supplier		

The interviews, which lasted between thirty and ninety minutes, were guided by an interview guide with a combination of open and closed questions plus according follow-up questions (cf. Section 3.3). The answers were recorded by audio and later transcribed to prepare the analyses. The compiled results of all interviews sent to the participants to give the opportunity of corrections or comments. In the conception of the interviews, recommendations from Kaiser (2014), Summers and Eckert (2013) and Petersson et al. (2015) were used as a guidance. Finally, in a workshop with collaborative researchers from social and communications sciences the connection between the empirical barriers and general barriers and collaborative engineering was built, resulting in the findings in Section 4.2.

3.3. Interview guide

The written interview guide consisted of five topics according to the dimensions of CAD-CAE integration of Herfeld et al. (2006), divided into 23 main topics for questions (see Table 2).

Table 2. Topics of the interview guide

Dimension of CAD-CAE integration	Topic for Question(s)
Product	Complexity of the product portfolio
	Phases of product development
Process	Concurrent engineering
	Simultaneous engineering
	Computer-based design analysis
	Frontloading
	Virtual product development
	Continuous improvement process
Tools	Generation of data
	CAD-integrated FEM systems
	Verification and validation
	Role of the simulation department within the product development process
Data	Information supply and information sharing
	Data management (PDM, SDM, PLM)
	Knowledge-based engineering
	Documentation of requirements and results
	Feedback for ongoing or past projects
People	Informal communication
	Mentorships and trainings
	Physical closeness
	Teambuilding and soft skills
	Coordination
	Trust in simulation results

To formulate suitable interview questions, the abstract research questions have to be transferred, a process known as operationalization (Kaiser, 2014). Figure 1 shows how the interview questions were derived from the research question using the SPSS method by (Heistinger, 2007).

Research Question:

1. Which barriers for the collaboration of design and simulation departments in German companies can be identified by expert interviews?

Analysis Dimensions

1) Product
2) Process
3) Tools
4) Data
5) People

Topics

1) Informal communication
2) Mentorships and trainings
3) Physical closeness
4) Teambuilding and soft skills
5) Coordination
6) Trust in simulation results

Finally chosen Interview Questions

Are the design department and the simulation department situated physically close to another?

- **Follow-up Question 1** (if no): Does this affect the collaboration negatively? Are other opportunities offered for communication?
- **Follow-up question 2** (if no): Why aren‘t both department merged together? Can you suggest ways of having regular communication without being physically close?
- **Follow-up question 3** (if yes): Which advantages are provided by the physical closeness?

Figure 1. Operationalization of the interview questions

4. Results

4.1. Models of collaboration

To categorize the findings of the individual interviews, the specific situation of the companies was described with regards to the position of the simulation department in the organizational architecture. Three basic architectures could be identified, depicted in Figure 2. The different architectures have a major influence on the existing barriers as shown in the following sections.

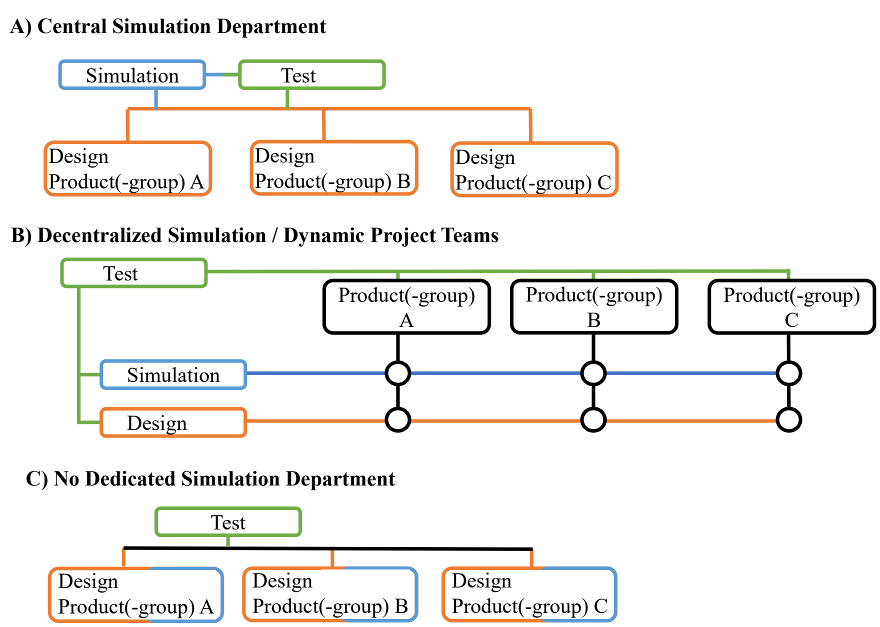

Figure 2. Architecture types of design and simulation departments

4.2. Barriers

As a main goal of the study was to identify barriers between design and simulation departments as stated in the main research question, first a definition of barriers was introduced.

In this study, everything that

- increases personal costs
- increases computing time
- worsens the quality of the simulation results
- leads to redundant or unnecessary simulations and iterations or
- prevents necessary collaboration at all

is defined as a barrier for efficient collaboration.
Based on this definition, a total of 20 barriers was identified as described in Table 3. The column "Freq." shows the citation frequency of the barriers in the expert interviews. It has a value between 1 and 16, as 16 interviews were conducted. The highest value is 9, though, for Barrier B08 *Information sharing towards the simulation department*.

Table 3. Set of 27 barriers identified in this study (alphabetical order)

#	Barrier	Description	Freq.
B01	Concurrent engineering	Parallel work often leads to rework in later stages of the development process as well as time and cost consuming change management, if not applied the right way. A lot of communication between all parties involved is necessary to keep in order to reduce unnecessary duplication of work or redundant work on models that are already outdated.	1
B02	Conflict of objectives between design, simulation, and test	Design engineers are mainly cost- and time-driven, while simulation experts are focused on the functionality of the product. Additionally, a lot of testing engineers, think that the increasing use of simulations is going to eliminate the need for testing and struggle to work together with their “opponents” from the simulation department.	1
B03	Coordination of design and simulation processes	The coordination of design and simulation processes becomes challenging when various design teams in different countries and time zones have to work together with the simulation department.	1
B04	Efficient frontloading and Dependency of simulation on design and test departments	For the collaboration of design and simulation departments, frontloading means conducting simulations as early as possible. However, design engineers have to develop detailed CAD models first, so that simulations can lead reliable results. The dependency on geometries from the design department leads to downtimes in the simulation department, as simulation experts have to wait for models to be generated and technology data to be transmitted. In addition, measurement data from the test department is needed to define boundary conditions.	2
B05	Explanation of complex issues vs. high documentation effort	Design and simulation experts often struggle to explain complex issues to the other department in detail, but easy enough to be understood for a non-expert. The problem of overestimating the notoriety of terms and specialized language is called *terminology illusion* in communication science (Rambow, 2000). On the other hand, detailed documentation processes require a lot of time, which could be used for conducting more simulations or designing and validating more product variants.	3
B06	Generation gap	Experienced employees that have been working in a testing-heavy environment and are used to simulations being not very reliable, are often hard to convince that the simulations nowadays can be an equivalent and reliable partner. Communication science speaks of *defensive routines* and the *common knowledge effect* when referring to the problem of only focusing on commonly shared pieces of information rather than accepting newly created knowledge, like that generated by the simulation department (Argyris, 1986; Argyris, 1990; Gigone and Hastie, 1993).	3
B07	Handling different human characters	When organizing the collaboration of two departments with many people, different human characters and their specific peculiarities have	2

		to be dealt with in order to make them work together as efficiently as possible.	
B08	Information sharing towards the simulation department	Design engineers often do not know, what kind of information simulation experts need to execute their simulations. The problem of experts finding it difficult to articulate their knowledge in a way that non-experts can relate to (cf. barrier 6), is also known as the *paradox of expertise* in communication science (Johnson, 1983; Hinds, 1999).	9
B09	Interdepartmental communication and feedback culture	People in general tend to interact more with likewise groups. In communication literature this is known as *in-group outgroup behaviour* (Blau, 1977). In many companies, there is no standardized way of providing feedback and no one is forced to provide feedback to the other department. This leads to the simulation department only getting negative feedback from design engineers and almost never getting appreciation for their work. A negative atmosphere between both departments is the result in many cases.	5
B10	Lacking acceptance and inadequate understanding of the capabilities of the simulation expert	When working with simulation experts, design engineers often do not know what they can expect from simulation experts. They have an inadequate understanding of how long the generation of reliable results takes and what kind of results are possible at all for a particular problem. Additionally, many design engineers Historically prefer to collaborate with the test department and do not see the simulation experts as equivalent partners (cf. barrier 7).	2
B11	Missing structures of collaboration (e.g. trigger points)	Due to the rapid growth of simulation departments in the last two decades, defined structures of collaboration or standardized processes for the collaboration have not been implemented yet in many cases. Missing trigger points lead to redundant work by the simulation department, since often by the time the simulation results are ready, the design of the component has changed and the results are outdated	2
B12	Mistrust in simulation results	Design engineers often do not trust in simulations. This leads to redundant work, because design engineers order simulations from the simulation department and after that, try to ensure the results with redundant tests by the test department. Communication literature refers to the problem of only listening to those insights that confirm the prior opinion as *cognitive bias* (Tversky and Kahnemann, 1974).	4
B13	No close coupling between departments	There are multiple design teams working in various locations around the globe. The central simulation department receives orders from all of them and from location and does not have a close coupling to any of the teams it is collaborating with.	2
B14	No customer focus	Simulation experts tend to work on the project they think is the most interesting as they do not know which has the highest priority from a customer perspective.	1
B15	Physical distance	Whenever face-to-face communication is not possible without effort, communication between two departments becomes worse despite modern communication programs. Physical distance also leads to another issue, known as the *hidden profile problem* in communication literature (Stasser and Stewart, 1992). It occurs whenever people have to work together and do not know the background of the other person (profile), especially when working across different time zones and cultures, as mentioned by Bohemia et al. (2012).	9
B16	Prioritization of simulation orders	Many design engineers fail to realize that the simulation department does not have the same overview about the whole product development process like they do and cannot prioritize simulation assignments on their own. Communication literature speaks of the *false consensus effect* when people assume that others see situations as they do and fail to revise their framing (Manzoni and Barsoux, 2002).	3

B17	Redundant time-consuming iterations	In many cases, after a simulation, design engineers change the design and start a new iteration. Due to misunderstandings, many of these iterations are redundant, as they do not generate the information required by the design engineer. In communication science this is referred to as *decision problem*, when the decision maker takes complex decisions without asking (Russo and Shoemaker, 1989). Additionally, when design engineers just want to quickly verify a certain feature, they need to start a time-consuming process of collaboration with the simulation department.	4
B18	Standardization in the presence of diverse projects	Collaboration of two interdisciplinary departments needs a standardized process to be efficient. The different projects at most companies, however, are too diverse to establish a standardized process that works for every single project.	2
B19	Unstructured information sharing	Missing structures for information sharing lead to the problem of transferred knowledge being stuck in the situation where it has been acquired, which is known as the problem of *inert knowledge* (Whitehead, 1929) or relevant information not being shared at all, which is known as *knowledge disavowal* in communication literature (Zaltman, 1983; Deshpande and Kolhi, 1989).	1
B20	Using CAD-integrated FEM systems efficiently	Design engineers need to be trained by simulation experts to be able to use CAD-integrated FEM systems to their full potential and they need to be monitored throughout their work in order to ensure that reliable results created.	5

For each of the 20 listed barriers, there are measures how to overcome them, either from literature or form the expert interviews themselves, as some interviewees describe measures that can help others to overcome their barriers.

4.3. Improvement opportunities

Within this paper, the term "Improvement opportunity" is used for the combination of an identified barrier from Table 3 and an appropriate measure to overcome it. A measure refers to a concrete action that can be undertaken by the management in order to realize the improvement potential. This section lists examples of improvement opportunities for some barriers as mentioned in the interviews, structured according to the dimensions of Herfeld et al. (2007). In some cases, companies have already implemented measures that could be helpful for others with the same barriers, too. Some measures are taken from literature (especially from Maier et al., 2011) and suggested for certain barriers. Improvement opportunities for each of the barriers cannot be described here due to length restrictions.

4.3.1. Tools

In the dimension of tools, mainly the topic of CAD-integrated FEM systems was important for many interviewees. Figure 3 compares some advantages and disadvantages of CAD-integrated FEM systems.

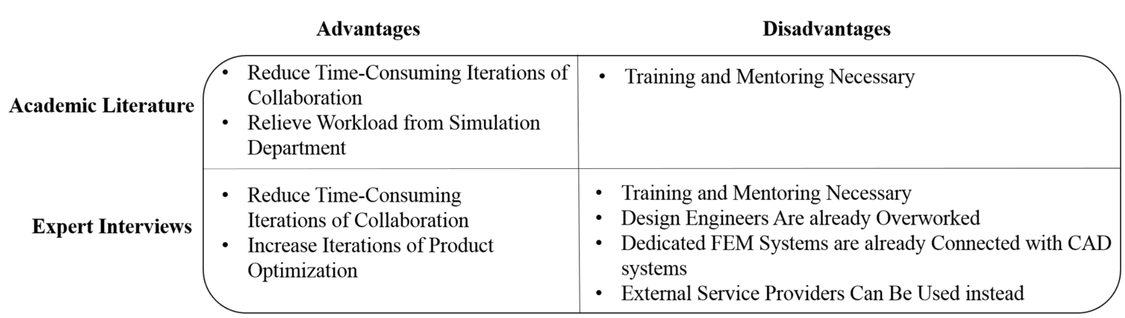

Figure 3. Advantages and disadvantages of CAD-integrated FEM systems

Based on these findings, the barrier of difficulties in the use of CAD-integrated FEM systems can be overcome by training and preparations conducted in the simulation department as shown in Figure 4.

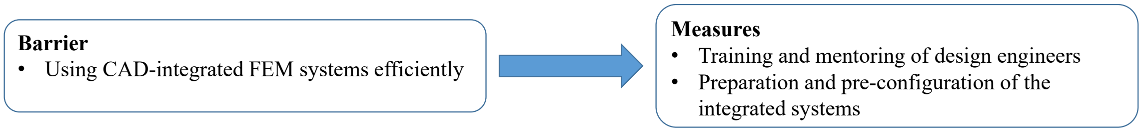

Figure 4. Usage of into CAD integrated FEM systems

4.3.2. People

In the domain of people, things get more complex as this is the crucial area for improvements in the field of CAD-CAE integration as shown above. While the initial and most obvious barriers of redundant iterations and missing prioritization can simply be overcome by more communications, this communication itself leads to further barriers. The appropriate improvement measures depend heavily on the architecture of the organization, namely the positon of the simulation department in the overall organization according to the findings in Section 4.1. Figure 5 shows the initial barriers as well as the resulting improvement measures and consequent resulting barriers.

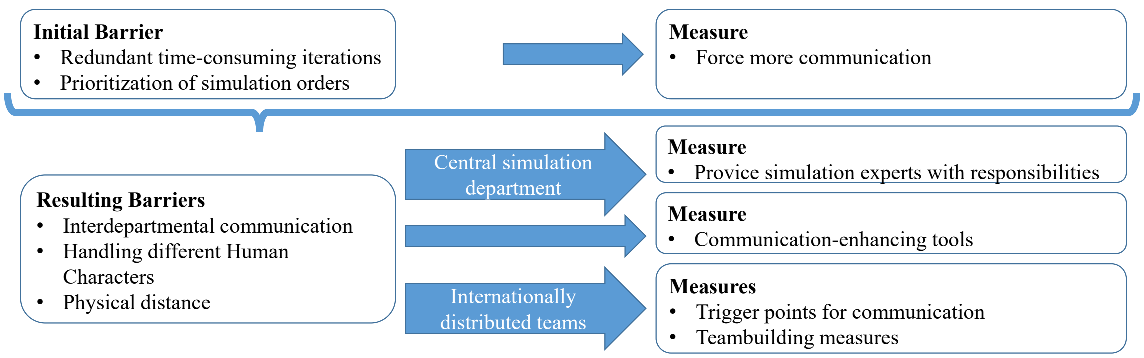

Figure 5. Improvement opportunities within the dimension People

4.3.3. Data

The improvement measures in the dimension data are also dependent on the circumstances, the company size in this case. As shown in Figure 6, the recommendations for smaller companies are on the personal level concerning routines and workflows. For example, simulation templates according to Petersson et al. (2015) can be implemented. For lager companies, on the contrary, software support is need in the form of integrating collaboration management tools.

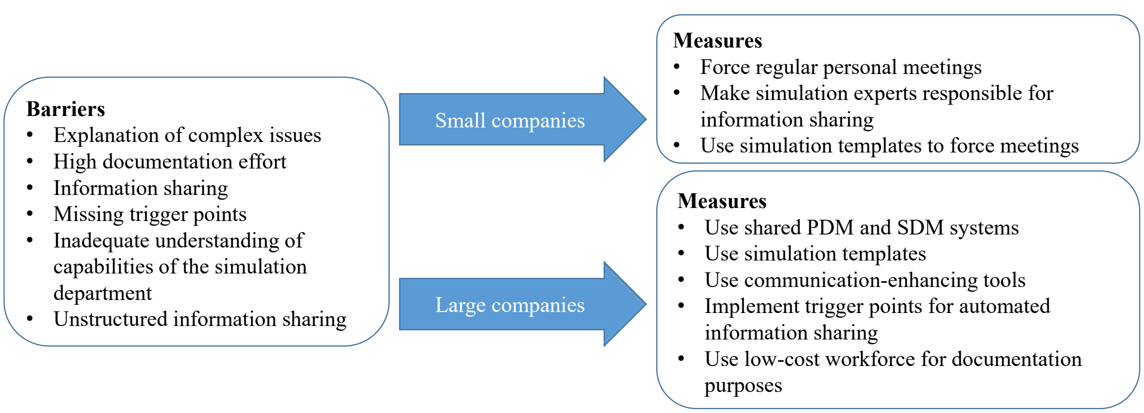

Figure 6. Improvement opportunities within the dimension Data

4.3.4. Process

As found in the interviews, a major challenge for most of the companies is a missing or inappropriate standard process. While its implementation has some advantages and helps to overcome the barrier of missing structures of collaboration and its negative effects, it also leads to subsequent resulting barriers as shown in Figure 7.

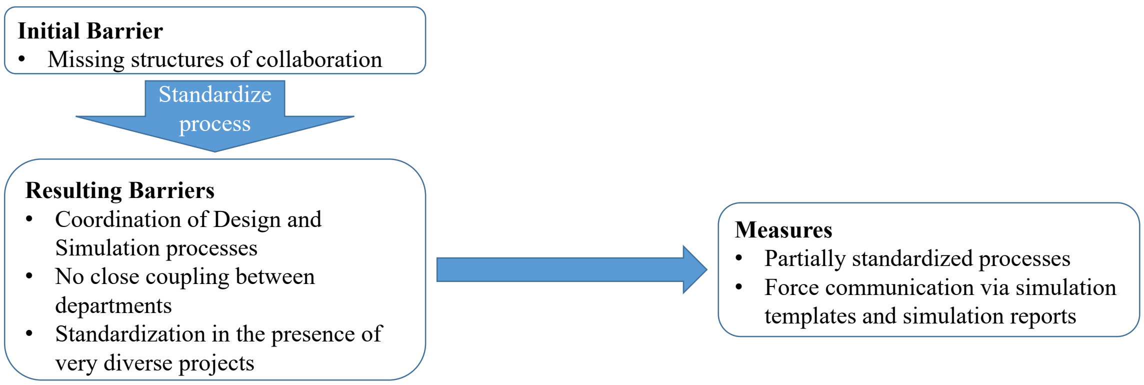

Figure 7. Improvement opportunities within the dimension Process

Again the resulting barriers as well as the improvement measures depend on architecture of the organization as shown in Figure 8, namely whether there is central simulation department or the organization consists of dynamic project teams.

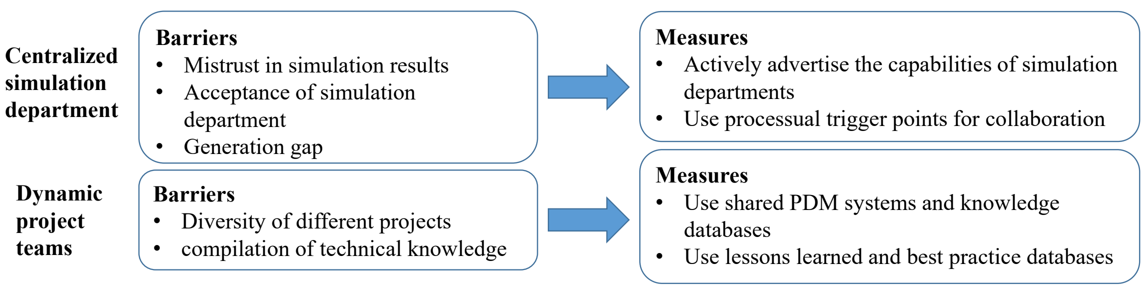

Figure 8. Improvement opportunities according to the chosen form of collaboration

In both cases, concurrent engineering can be applied and is necessary in most cases as stated by the interviewees. Figure 9 shows the resulting improvement opportunities.

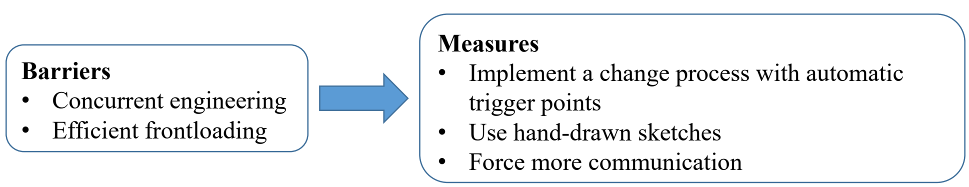

Figure 9. Improvement opportunities for concurrent engineering and frontloading

4.3.5. Product

All of the findings in this paper are dependent on the circumstances of a specific company and the resulting improvement measures need to be adjusted. However, they are not specific to a certain industry of a special class of products. As a consequence, also the findings in the dimension process is related to the findings in other dimensions such as process and people (cf. Figure 10).

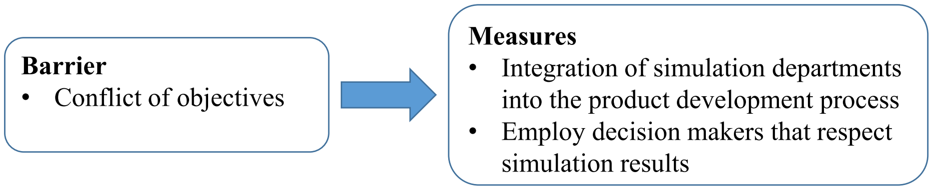

Figure 10. Improvement opportunities within the dimension Product

5. Conclusion

5.1. Discussion

Three areas have to be investigated when judging the validity of this interview study: the selection of the experts, the generalization of the findings and the influence of the interviewing persons on the results. Concerning the selection of experts, all experts had worked together with the researchers before in some kind of project or had met the researchers on other occasions before except one. As a consequence, all of the were working in the research filed of this study in a way or another, which may result in a certain bias towards the importance of improving the process of product development in general or even improving the process of collaboration between design and simulation departments.

For the generalization of the findings, it has to be questioned, if all of the identified barriers really represent a practical and constantly occurring problem within the collaboration of design and simulation departments or are just subjective issues in the everyday life of singe persons. However, most barriers could be matched with general barriers for communication and collaboration of people or teams of any thematic field that can be found in common communication literature. It could be shown that most barriers found by the interviews can be led back to universal problems of communication. Additionally, no barrier was only mentioned by one single person. Thus, it can be assumed that most barriers really have a practical relevance, since every single barrier was mentioned by at least two experts independently. Furthermore, Kaiser (2014) postulates that qualitative expert interviews do not aim at generating results that are generalizable beyond the investigated case, but serve to understand the particular case based on a methodical analysis. Because a generalization is neither wanted nor needed, there is no need to interview a representative sample of experts or even all relevant experts for the particular topic. Additionally, because of the broad spectrum of experts it was also assured that the topic is evaluated from the point of view of every participant within the process of collaboration, supported by the very broad range of companies was interviewed, ranging from below 1.000 to over 84.000 employees, from automotive industry, mechanical engineering, and household appliances to nuclear technology suppliers and from companies with one simulation expert to companies with over 100 simulation experts.

In order to not influence the interviewees and their answers in any manner all questions were formulated as open as possible. No suggestions for possible answers or valuations for a particular answer were used in the wording of the questions to prevent any influence on the answers.

5.2. Outlook

As a part of this paper, improvement opportunities could be identified in order to improve the collaboration of design and simulation departments and to increase the efficiency. Three types of improvement opportunities could be found: First, improvement opportunities that are already identified by interviewed experts within their own company and the particular improvement steps are implemented at the moment in order to overcome the associated barrier. Second, improvement opportunities that are suggested by interviewed experts. The particular barriers are already identified within the company and the experts propose certain improvement steps that should help to overcome the particular barriers. And third, improvement opportunities that are suggested by the author of this thesis. The particular barriers are already identified, but experts struggle to find improvement steps in order to overcome these barriers within their company. For further investigation the following questions could be reviewed by conducting industrial case studies: Is it possible to transfer improvement opportunities of type 1 to overcome barriers at other companies, where experts struggle to find improvement steps? Which of the improvement opportunities of type 2 and 3 do really improve collaboration of design and simulation departments when implemented into the product development process within the particular companies?

Next steps include graph-based considerations to take into account different domains of collaboration between design and simulation departments - namely persons, artefacts, tasks, and tools as presented in Schweigert et al. (2017a) to connect barriers and recommendations in a more systematic way.

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