

## Industrial Evaluation of a Toolkit of Methods for Engineering Knowledge Management of Simulations

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Simulations offer the potential of improving product and development process quality. However, a lack of overview of existing simulation methods and of documentation may make it difficult to apply them efficiently along the entire development process. To tackle this problem, a knowledge-based framework was developed to enhance simulation knowledge management, give an overview over all possible simulations, and provide means to standardize simulation processes for experts. This paper presents the first industrial evaluation of the framework concept by two workshops. The results exhibit a wide interest in the knowledge-based framework in industry and demonstrate aspects for further industrial application. Critical points particularly include an intuitive user interface and the integration into the specific IT environment of a company, which will be the next steps for evaluating the system in industrial conditions.

keywords: knowledge management; toolkit of methods; industrial evaluation; simulations

### Introduction and State of the Art and Research

Simulations play an increasingly important role in the design of technical systems. They open up the chance of improving products, as well as the procedures by which products are designed, and deal with the complexity of engineered systems (Karlberg, Löffstrand, Sandberg, & Lundin, 2013, Koziel 2010). Consequently, these improvements may lead to



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higher quality standards and a simultaneous reduction in costs. Applications of simulation methods in the design process are vital and include parametric optimization to evaluate different design variants (Sobester & Forrester, 2015) and the quantification of uncertainties (Allaire & Willcox, 2014), just to name a few. (Koziel & Leifsson, 2016) Despite their rising application in product development processes, however, simulations are yet far from being optimally used along the entire development process (Pavasson et al., 2014; Novak et al., 2012). This is often due to a lack of overview of available simulation methods. Currently, knowledge-based simulation solutions primarily exist in the context of specific assistance functions, like the one presented in Bernst, Kaufmann & Frochte (2016), but do not support a general procedure, applicable along the entire development process.

Additionally, people that are inexperienced with simulation methods, such as design engineers, may not have the proper knowledge to apply simulation methods correctly. This leads to the research question: “How must an assistance system be designed to support knowledge management in the context of mechanical simulations?”

To answer this question, a toolkit of methods within a holistic knowledge framework has been proposed to achieve a better overview as well as a more standardized procedure for simulations along the product development process (Carro Saavedra, Schrieverhoff & Lindemann, 2014). The evaluation of the framework concept is now the topic of this paper.

The framework was filled with the concepts and methods developed within the FORPRO<sup>2</sup> project. The project FORPRO<sup>2</sup>, which was initiated in the end of 2013 and lasted till the beginning of 2017, had the goal of conducting research on means of increasing the efficiency of both product development and manufacturing process development. It consisted of ten subprojects from university, with a research focus divided into three areas: knowledge management, product simulation, and manufacturing process simulation. The developed framework of this paper was part of the knowledge management research group. Alongside the academic research partners, the project also included more than 25 industrial partners that ranged from small over medium to large companies. While the research areas on product and process simulation developed novel concepts for knowledge-based simulation support, the subprojects on knowledge management were intended to tackle knowledge-based applications in the development process with the goal of better integrating simulations in the design process (see Figure 1).

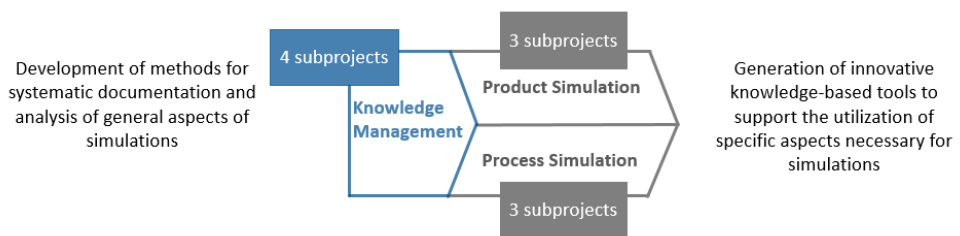


Figure 1 Division of the FORPRO<sup>2</sup> project into three research areas with three to four subprojects each. source: Carro Saavedra et al., 2014

The procedure to fill the toolkit with the methods from FORPRO<sup>2</sup> is presented in Carro Saavedra et al. (2016). The procedure can also be applied to gather and structure the

knowledge from different departments, in order to come up with an individual framework for the content of the company (Carro Saavedra et al., 2016). Consequently, the next step after presenting the toolkit concept and its development in the aforementioned papers was to evaluate the prototypic toolkit in an industrial environment.

This paper therefore presents and evaluates the results of two industrial workshops. After a brief review of the framework concept, the following sections explain the workshops and evaluation methodology. Finally, the results and impressions from the workshops are gathered and compared to draw conclusions about the evaluation and propose directions of further research and improvements of the framework concept.

## **Framework Concept**

This section briefly explains the structure and the idea behind the framework. Subsequently, a closer look will be taken at the specific contents of the toolkit.

### *Components of the Framework*

In order for the framework to lead to an enhanced structuring, higher transparency, and better integration of various simulation techniques into the development process and thereby support the design of technical products, the framework is divided into three main components: the user interface (UI), the main part of the toolkit of methods itself (TKM), and the knowledge base (KB).

The user interface aims at providing a starting point for the user to find proper simulation methods and apply them correctly. Therefore, it contains all possible goals or development situations the user might encounter and that are addressed by respective methods in the toolkit. Furthermore, it lists the necessary steps in order to reach these goals and to help the user identify the right method for his or her current development task.

Building up on the workflow of the UI, the toolkit of methods supplies concrete methods that can be applied in order to fulfill the goals of the current procedural step. To provide the necessary flexibility to the user, the toolkit is subdivided into three different levels: the general level (G), the application-specific level (AS), and the project-specific level (PS, see Figure 2). On the general level, generic information about the method (e.g. finite element simulation) and its pros (e.g. possibility to capture local effects) and cons (e.g. time-consuming) are provided. On the application-specific level, this basic information is concretized towards a certain application (e.g. finite element simulation for deep drawing). Lastly, on the project-specific level, the information from the application-specific level is further concretized towards a certain project, in which the respective method has already been utilized (e.g. finite element simulation for deep drawing of a door covering). Each of the different levels in turn contains various fields that capture aspects like objectives, pros and cons, and hints for the application of the method on that specific level and structure its information. (Carro Saavedra et al., 2016)

The user is meant to first look on the general level to see if a suitable method has already been incorporated into the toolkit. If that is not the case, the user may be the first one applying this method in his or her company or the method has not yet been documented. If the method has been documented though, the user is then supposed to check if he or she finds his or her application for this method on the application-specific level. If no suitable applications are found, the user uses the information and files provided on the general level (see path 1 in Figure 2). In order to use the files provided in the knowledge base, the user will need to adapt the general file templates as well as the procedures for

his or her specific application. Thereby, the user is left with less work than coming up with the file from scratch. Furthermore, the process is less prone to error, since more general files and methods are provided that are then concretized, rather than using specific knowledge from one project and trying to transfer it to yet another project that might have completely different boundary conditions.

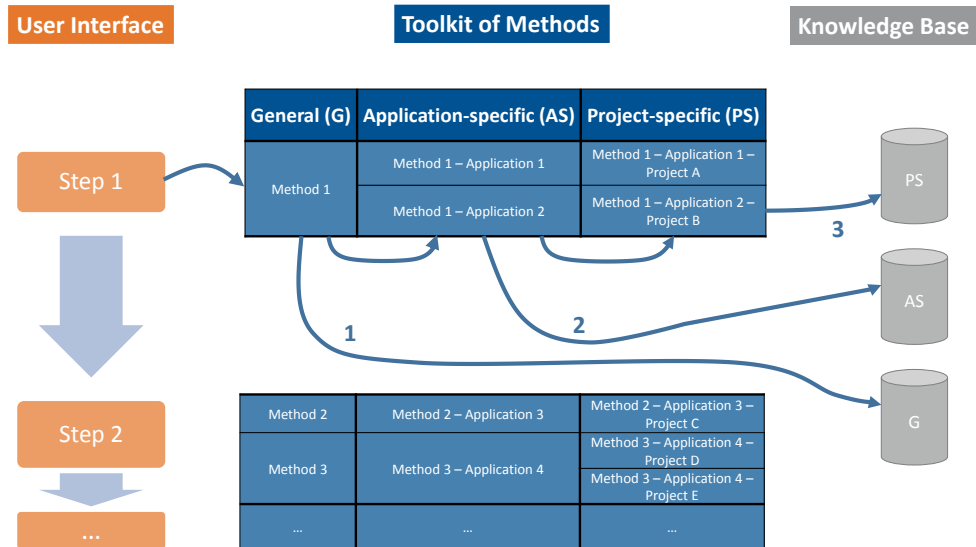


Figure 2 Workflow of the connection between the User Interface, the Toolkit of Methods, and the Knowledge Base.

In case the user finds an equivalent application, he or she is supposed to check the project-specific level and see if even an equivalent project is documented there. If no projects are found, he or she can use the information and files from the application-specific level and adapt them according to the specific project (path 2 in Figure 2). In case an equivalent project is found, he or she may directly use the information and files from the project-specific level (see path 3 in Figure 2).

If the paths 1 or 2 are taken, the user may fill the more specific levels, after he or she is done performing the simulation. This part of the workflow is not depicted in Figure 2 due to simplicity. Consequently, the next user that encounters a similar or equivalent situation can start from one of the specific levels and build on the knowledge provided by colleagues. Overall, this division helps towards standardizing simulation processes and make them applicable to a larger amount of development situations instead of merely providing the project-specific information.

### Specific Content of the Toolkit of Methods

At the point of time of this submission, the framework had only been realized in tables where the mere information is gathered, structured, and visualized. This current status represents a preparation for the implementation in an actual software prototype.

The toolkit contains all developed simulation modules and methods for simulation management from the FORPRO<sup>2</sup> project. Each one tackles a specific objective along the development process and provides actions to assist and improve the usage of simulation knowledge. Table 1 shows the contents of the user interface. In addition to the description and the objective of the method, each point in the user interface includes a number of steps. Each of these steps may refer to various methods in the toolkit of methods, as depicted in Figure 2 – Step 2.

*Table 1 Overview of the current contents of the user Interface including their respective source in literature.*

<b>Index</b>	<b>Description</b>	<b>Objective</b>	<b>Literature sources</b>
1	Manufacturing-specific Structural Optimization	Structural optimization towards required mechanical capacity under minimal material requirements and process-specific design	Hautsch et al., 2015
2	Finite Element Analysis Assistance System	Execution of simulations with support of the FEA Assistant	Kestel & Wartzack, 2015; Kestel, Sprügel, Katona, & Wartzack, 2015
3	Patch Optimizer	Enabling communication flow via a CAD model	Goller et al., 2016
4	3D Surface Registration	Validation of a simulation with an ideal 3D model; methods for the model preparation with real geometric elements	Katona, Lušić, Koch & Wartzack, 2016
5	Pressure Casting Simulation	Design of casting geometry suitable for manufacturing	Heilmeier et al., 2016
6	Estimate Simulation Quality	Identification and adaption of suitable parameters	Otten, Schmid & Weber, 2016
7	Simulation Management	Analyze applications of simulations and optimize their integration within the product development process	Carro Saavedra et al., 2014
8		Improve the communication between design and simulation departments	Carro Saavedra et al., 2016; Schweigert, Carro Saavedra, Marahrens & Lindemann, 2016

In the last column of Table 1 publications with regard to the described methods are documented. This is only an exemplary filling of the toolkit and by no means complete. It rather serves as a central element for gathering and documenting the developed methods within the research project and for a first concept evaluation in an industrial environment.

## Evaluation Plan and Methodology

In order to assess the prototypic framework, workshops in two major German companies were performed. They were intended to transmit the basic ideas of the framework usage and toolkit content, have the participants apply the concepts on their own and finally discuss and document their experiences by means of a questionnaire. In the following, the procedure of the workshops, as well as the questionnaire used for evaluation are presented.

### *Workshop Settings*

The two companies for the workshops were selected because of their involvement in the design of the framework from the beginning. Furthermore, due to their size they had the potential to integrate such a system into their IT infrastructure. Both workshops had a duration of three hours. Workshop A was held at the research institute while workshop B was conducted at the company.

The performed workshops both focused on finding out if employees accept the concept of the framework and if the concept is understandable. Additionally, the evaluation was also intended to get further stimulations and find improvement potential for a final realization. In order to include a combination of people with various backgrounds, people from design, from process management as well as from simulation departments were invited in both companies. This was done for two particular reasons.

Firstly, the framework was intended especially to support the collaboration between design and simulation departments.

Secondly, insights from inexperienced simulation users, usually from the design department, as well as simulation experts coming from the simulation departments could be taken into account in this way.

Regarding their prior knowledge, the two companies had different starting points. Most participants from company B (a simulation department manager, a process manager, a simulation expert, and a design engineer) were informed about the framework concept, but had not yet had deeper insights into its contents and application to an actual development process and to specific simulation methods. In company A on the contrary (an innovation department manager, an innovation manager, and a two production experts), only one of the participants (the department manager) had been in touch with the framework and its contents prior to the workshop.

All of the participants had multiple years of work experience in the field of simulation-assisted product design.

### *Workshop Procedure*

Both workshops were started by introducing the concept of the framework. Therefore, it was of particular interest to transmit the idea of the user interface with its relation to the toolkit of methods. Furthermore, the division of the toolkit into different levels, as well as the subdivision of these levels into categories was outlined.

It was essential to point out to the participants that the workshop was not about the implementation of the framework. Therefore, before examples from the framework were shown, an oral explanation (workshop A) or a few short video clips (workshop B), which demonstrated a possible web interface for the framework, were presented.

This was done in order for the participants to get an idea what the final system might look like and how they would interact with it as well as to explain that no final software prototype was to be evaluated. For the rest of the workshop, the participants worked with the media elements shown in Figure 3. To give them first-hand insights, some examples were presented until all participants had a basic notion of the framework concept, especially about the division of the framework into user interface, toolkit of methods, and knowledge base as well as the three levels of the toolkit.

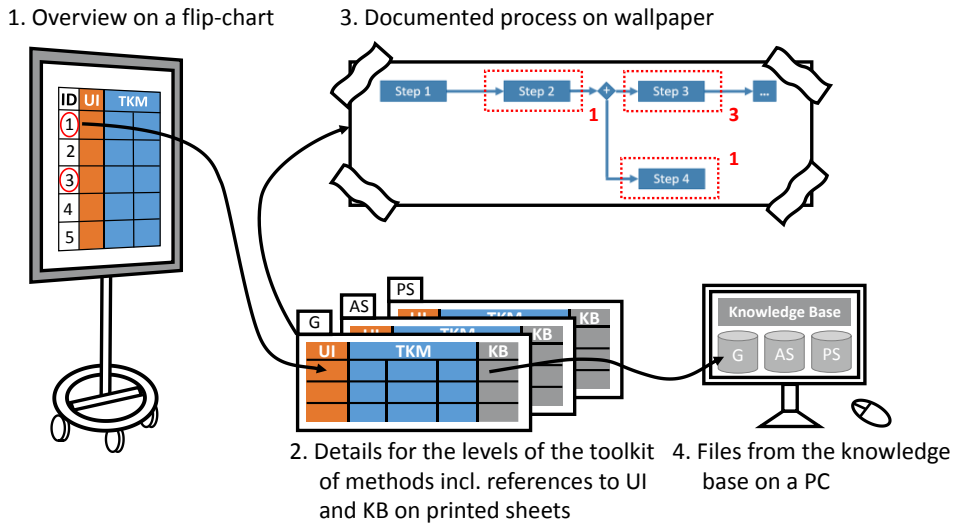


Figure 3 Workflow of the workshop with the different media elements

Subsequently, the participants were shown a flip chart depicting a table with the overview of the contents of the framework (Figure 3, step 1). Further information for each method was provided in tables that were printed on paper sheets (Figure 3, step 2). Based on the different methods contained in the overview and specified in the tables, the participants were asked to identify methods within their process model that was shown on a poster (Figure 3, step 3, marked in red dashed boxes). To give the participants a more realistic idea of the methods, files from the knowledge base were provided on a computer that could be examined by the participants and was supposed to demonstrate how the participants may benefit from the available resources contained in the framework (Figure 3, step 4).

For workshop A, for which no documentation of a company process existed, the participants first had to collect a process sequence with all its steps and aspects. Based on this information, they were asked to identify possible tasks, where methods from the exemplary framework contents shown in Table 1 may be applied.

Contrary to that, workshop B was based on a previously documented process description in form of a BPMN diagram (Business Process Model Notation, schematically depicted in Figure 4). First, the participants were asked to go through each step and either identify the company-specific methods they normally apply or look for methods from the toolkit that could be used. After all methods according to the process steps had been gathered, the participants worked on filling the framework with best-practice experience. This included the recording of pros and cons of a respective company-specific method and the steps necessary to perform it (dashed arrows in Figure 4).

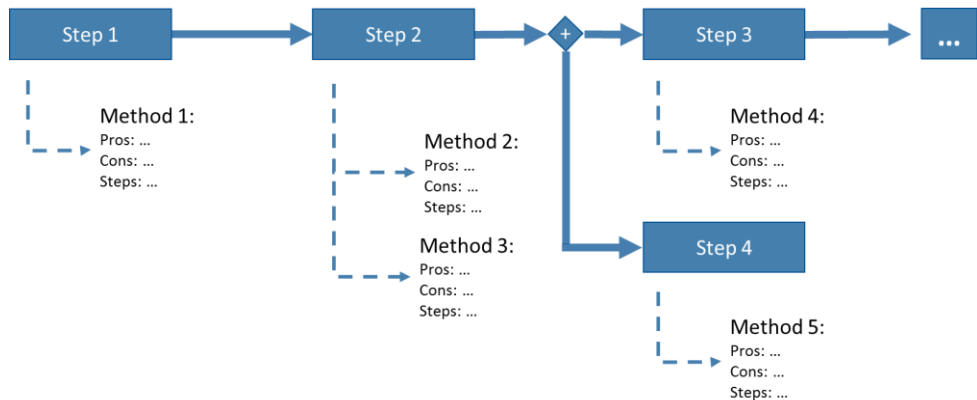


Figure 4 Basic procedure of identifying the methods along the process

### Questionnaire

To take note of individual experience, a questionnaire was given to each participant at the end of both workshops. In this questionnaire, the participants were asked to rate different statements with five possible answers, representing their level of agreement with that statement (see Figure 5).

All statements were supposed to be answered with one out of five choices, ranging from complete agreement over neither agreement nor disagreement to complete disagreement. The only exception was statement 17 that was supposed to be answered with merely yes or no. All questions that are followed by a line had the possibility for individual answers.

I agree <input type="checkbox"/>	I tend to agree <input type="checkbox"/>	I neither disagree nor agree <input type="checkbox"/>	I tend to disagree <input type="checkbox"/>	I disagree <input type="checkbox"/>
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Figure 5 Possible answers of the questionnaire that were handed out to the participants in both workshops

As shown in the box below, the questionnaire is divided into three different categories: feedback on the structure (I.), feedback on the application to an example process (II.), and feedback on the benefits and objectives of the toolkit of methods (III.).

In the various statements, the participants were confronted with both general aspects about the necessity of a knowledge-based system as well as specific aspects regarding the first impressions and application of the framework and the toolkit of methods by the participants. Additionally, some questions left room for individual answers and feedback. The first category was meant to capture how the concept of the framework and especially the division of the toolkit into different levels was perceived by the participants. A particular interest lay in finding out if the structure is easily comprehensible and how the participants would rate benefits of using it. Furthermore, the participants were given the chance to leave their personal comments about the division, so that they could cross out or add categories they would have found useful. The first section was finished by asking the participants how the structure could be improved.



In the second section, the experience of the participants in applying the toolkit to an actual example process was captured. Here again, a particular focus was on the comprehensibility and benefits they experienced during the application. Finally, the participants were given the chance for individual answers on improvements regarding the application.

The last category was meant to supply deeper insights into the company perspective on the framework and knowledge management in general. Therefore, the questionnaire asked for the importance of knowledge management and previously implemented knowledge management systems in the company. Furthermore, it was intended to get first impressions on how realistic an implementation of the toolkit within the respective company was. The last two questions provided room for overall positive or negative points on the toolkit.

After explaining the intentions behind the workshop and specifically the questionnaire, the following sections present the specific results from the evaluation.

**I. Feedback on the structure:**

1. The division of the framework in user interface and toolkit of methods is comprehensible.
2. The division of the framework in user interface and toolkit of methods is beneficial.
3. The user interface is comprehensible.
4. The user interface is beneficial for getting an overview of the contents of the toolkit of methods.
5. All columns of the user interface are beneficial.

Please cross out or add columns in case you disagreed with this statement.

Goal of the simulation element	Procedure
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6. The division of the toolkit of methods into three levels (general level, application-specific level, and project-specific level) is comprehensible.
7. The division of the toolkit of methods into three levels (general level, application-specific level, and project-specific level) is beneficial.
8. All columns on each level are necessary.

Please cross out or add in case you disagreed

What are the foundations of the method?				Objectives
Name	Definition	Procedure during method application	Related documents	

What is the knowledge about the method application?				
Pros	Cons	Limits	Hints for its application	Linked files in the Knowledge Base

9. The division of the levels into various categories (foundations, objectives, and knowledge) is comprehensible.
10. The division of the levels into various categories (foundations, objectives, and knowledge) is beneficial.

What are your improvement advices on the structure of the toolkit of methods? \_\_\_\_\_

**II. Feedback on the application on an example process:**

11. The toolkit of methods is generally applicable to an example.
12. The methods in the toolkit of methods can be easily found.
13. The application of the toolkit of methods leads to beneficial results.
14. The toolkit of methods helps in applying new methods correctly.
15. The toolkit of methods helps with the integration of simulation within product development

How can the application of the toolkit of methods be generally improved? \_\_\_\_\_

**III. Feedback on the benefits and objectives of the toolkit of methods:**

16. There is a demand for knowledge management in my company.
17. There is a comparable system to the toolkit of methods in my company.  
If so, please explain briefly. \_\_\_\_\_
18. The documentation of the methods is important and reasonable.
19. The documentation of the methods with the toolkit of methods is beneficial.
20. The implementation of the toolkit of methods in my company would be reasonable.
21. The implementation of the toolkit of methods in my company is realistic.

How would you evaluate the toolkit of methods as a whole? \_\_\_\_\_

What did you find particularly positive? \_\_\_\_\_

What did you find particularly negative? \_\_\_\_\_

## Evaluation Results

In both workshops, a total number of seven people filled out a questionnaire, out of which three people participated in workshop A and four people participated in workshop B. At first, this section will jointly discuss the two workshops with respect to the feedback on the different components and scenarios. Subsequently, it will go into the specific details of each workshop separately.

In order to perform the evaluation mathematically, we used the following equivalent point system from 1 to 5:

1 - I disagree / Yes, 2 – I tend to disagree, 3 – I neither agree nor disagree, 4 – I tend to agree, 5 – I agree / No.

The questionnaire did explicitly not use a finer granulated Likert scale (e.g. a 7-point system), since the number of participants ( $n=7$ ) was comparably low. By using a 5-point system it was ensured that the number of possible answers was at least lower than the number of participants. (Likert, 1932)

### Overview

Figure 6 gives the results from the questionnaire for four exemplary questions from all three sections. The orange line marks the division between participants of workshop A (participants 1 to 3) and participants from workshop B (participants 4 to 7). The first and second graph (marked a) and b) in Figure 6) only include two people from workshop A rather than three, since one participant did not put a cross to rate the respective statement and therefore left no data to be evaluated.

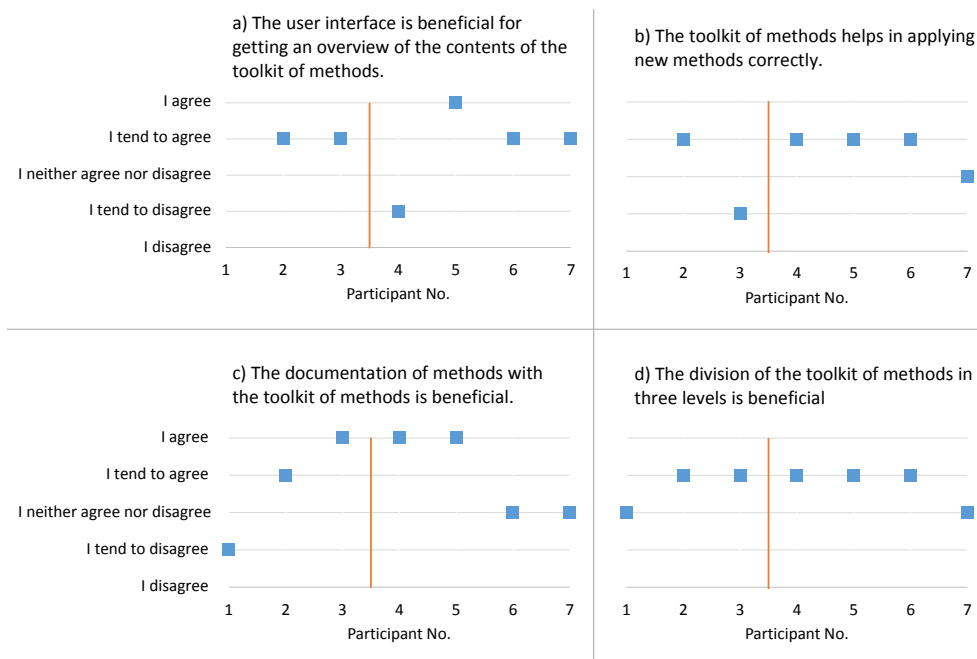


Figure 6 Answers on representative statements from all three categories

## *User Interface*

In the questionnaire, the great majority agreed that the user interface is beneficial and helps in getting an overview of the contents of the toolkit of methods (see Figure 6a). Regarding the comprehensibility, slightly more than half of the participants found that the user interface is comprehensible. Following up on this finding, more than two thirds of the participants found the division of the user interface beneficial, whereas slightly less than half found that all columns of the division of the user interface were actually beneficial for its usage.

Overall, the user interface was agreed to be comprehensible and beneficial. Only regarding the references, some participants wished to have additional, more general goals that in their view would help find methods in the toolkit more easily.

## *Toolkit of Methods*

Regarding the toolkit of methods, the great majority agreed that the division into three different levels is beneficial (see Figure 6c). Additionally, the majority of the participants at least tended to agree that the division of the toolkit of methods and its subdivision are comprehensible and specifically beneficial for the documentation of methods (see Figure 6b). With respect to its applications, the opinions were quite diverse. Whereas most participants agreed that the toolkit of methods helps in applying new simulation methods correctly (see Figure 6d), slightly less than half agreed that methods could easily be found in the toolkit of methods. In contrast to the majority agreeing that the division of the toolkit of methods is beneficial, only few of the participants agreed that the application of the toolkit of methods leads to beneficial results. Furthermore, only a few agreed that the toolkit of methods helps with the integration of new simulation methods in the product development process.

In general, however, the toolkit of methods was agreed to be comprehensible and beneficial. Only concerning its application, the participants responded with less agreement. Especially the integration into the development process was regarded specifically beneficial by most participants. A possible explanation for this fact might be that the workshop only presented the concept in form of printed tables. Therefore, the integration into the development process that would be performed in form of an IT system is yet a completely different story.

## *Benefits and Objectives*

The two strongest statements, which all participants agreed upon, were that in both companies, there indeed is a demand for knowledge management and that documentation of the available simulation methods is both important and reasonable. Furthermore, nearly all participants agreed that no comparable system to the toolkit of methods exists in their company or is at least not known to them. Merely one participant mentioned guidelines for the simulation department and checklists.

The strong agreement on the objectives and benefits of the framework underlines that there definitely is a strong demand for improved knowledge management in industry. The only comparable solutions mentioned were checklists and guidelines, which are not able to fulfill both the needs for expert users as well as inexperienced users, nor provide a holistic solution including various departments.

Figure 7 shows the median answers of all participants as well as their mean deviation from that median. It clearly sticks out that with the exception of participants 1 and 7, all participants tended to agree to most statements. Furthermore, most participants stayed entirely within the range of agreeing answers and gave no clearly disagreeing answers to most statements.

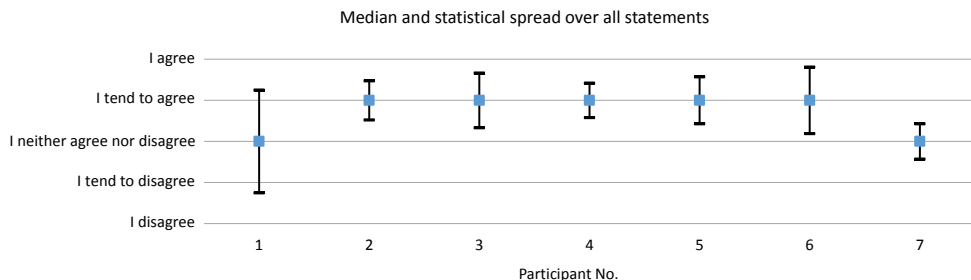


Figure 7 Median and upper and lower bound of the mean deviation from the median over all statements for each participant.

In order to calculate the mean deviation from the median  $s$  we used the formula

$$s = \frac{1}{n} \sum_{i=1}^n |x_{Median} - x_i|,$$

where  $x_i$  represents the different point equivalents to the answers given by the participants,  $x_{Median}$  is the median value over all answers of the participant and  $n$  the total number of statements the participant answered.

### Separate Considerations for Workshop A and Workshop B

In workshop A, the tendencies of the answers were a bit more diverse. Furthermore, six total statements were rated by at least one participant with disagreement, whereas there were only two in workshop B (see Figure 8).

To some extent, this might have been due to the fact that only three people participated in workshop A and the workshops included people that seemed to be less open to the idea in general. Particularly one participant seemed to disagree on many statements, along with leaving almost half of the boxes blank (participant 1 in Figure 7). Nonetheless, for some questions tendencies were also quite diverse in workshop B as shown in Figure 6a, but were overall less frequent. As opposed to workshop B, a lot less individual feedback was given in workshop A. In workshop B, most participants had already heard about the framework concept and due to an available process model, the application of the framework consisted of extracting simulation methods from their development process and transferring them to the framework. A significant part of workshop A was spent on documenting the process that was then used to identify sections where simulation methods of the exemplarily filled framework could appear.

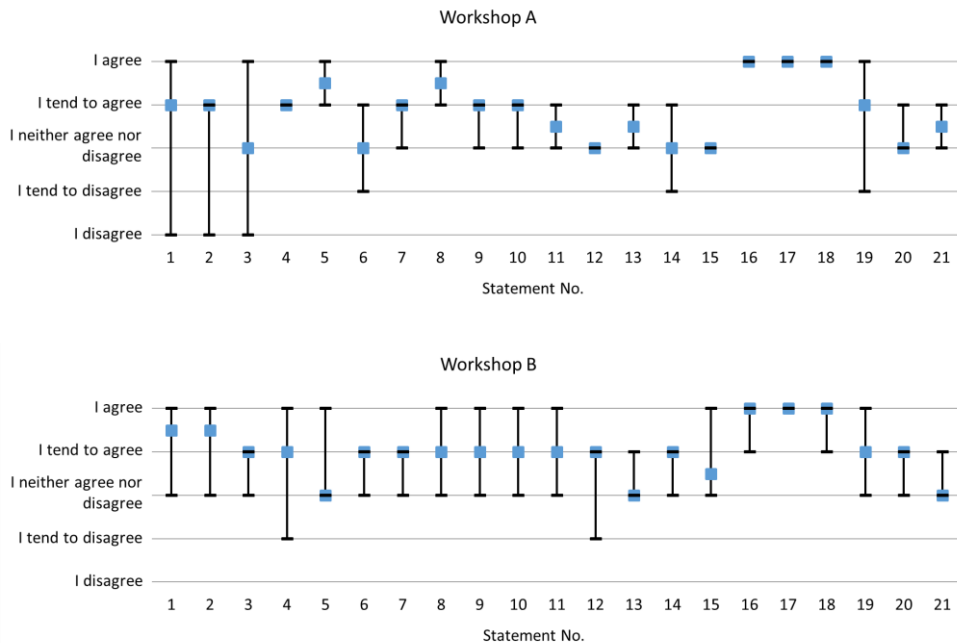


Figure 8 Median and Min/Max value for each statement for both workshops separately.

Some of the more negative results from workshop A may be explained by the different workshop format. Due to the absence of a documented process model, a lot less time could actually be spent on applying the toolkit of methods as the participants from company A did not work on filling the framework with their own simulation contents. Furthermore, the application that was done was a lot less specific to the company, since they worked with the present contents of the toolkit of methods, rather than filling it with their own methods in most cases. Consequently, the results achieved in the workshop with company A were less specific to their own process and did not include the step of identifying own simulation methods along the process and transferring them into the framework. Therefore, their impression on the application was far less concrete than in workshop B. This might also explain the fact that none of the participants of workshop A agreed that an implementation of the toolkit of methods in his or her company is reasonable, whereas in workshop B most participants did agree. Furthermore, it underlined how important process knowledge is for the application of our method. In workshop B, most participants answered all questions and gave constructive individual feedback on what they thought was still missing or could be improved. For example, several participants wished the toolbox had more general goals or keywords that seemed to be more tailored for an inexperienced user. Most of the participants agreed that an implementation of the toolkit of methods in their company would be reasonable, although only one out of four agreed that an implementation is somewhat realistic. Some comment included that for making such a decision, a cost estimate would be necessary.

The differences in answers in the questionnaire relates to the very different behaviour of the participants in the two workshops. The distance to the actual application of simulations methods in their daily working routines of the participants of workshop A was greater by far than to those of the participants in workshop B. Furthermore, the maturity level of software assistance in company A is higher than in company B, which also lowers the potential benefits of introducing such a system.

Figure 9 shows an extract of the documented process from workshop B in form of a model in Business Process Model Notation (BPMN). The legend gives an overview over the different elements, as well as the departments that correspond to the respective box coloring. The red dashed boxes mark methods from the toolkit that were identified within the respective process step, whereas the numbers next to the boxes mark the index of the method depicted in Table 1. As Figure 9 demonstrates, several methods from the framework were found in the documented process model, some even appearing several times throughout the process flow. Additionally, the participants were able to identify a method from their own process step called “Comparison Calculation and Test” that was then integrated into the toolkit of methods.

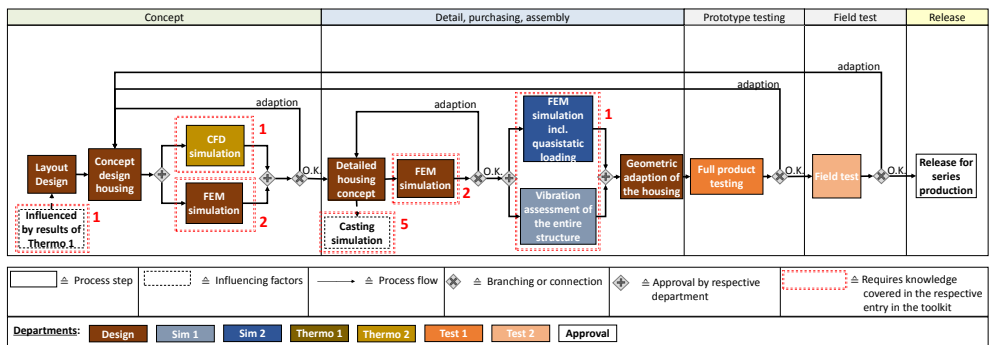


Figure 9 Documented process with identified elements from the User Interface presented in Table 1 (depicted numbers refer to the indices in Table 1).

This different perspective in both workshops also roots from the level of cooperation prior to the workshop. Whereas there was an intense collaboration with the industry partner of workshop B that included monthly meetings and two publications (Schweigert et al., 2016; Carro et al. 2016), the evaluation workshop was the first meeting with the industry partner of workshop A in the last two years. As a result, one of the participants in workshop B, who is in the position of a department manager, was familiar with the toolkit and its development and acted as a moderator in some phases of the workshop. It can be concluded from this example that such an abstract topic needs profound knowledge and familiarity with the corresponding tool to use its potential.

The two workshops also cannot be seen as entirely independent. Workshop A proved the necessity for a deeper understanding of the framework and its concept. As a result, the introductory part was lengthened and intensified in workshop B. In combination with the higher familiarity with the topic of the industry partner of workshop B, the focus of the participants of the workshop was more on the actual topic – the concept of the toolkit of methods – and less on technical issues like implementability. Therefore, the authors believe the results of workshop B to be more profound and meaningful – regardless of their being more positive.

## Conclusion

Most participants found that the toolkit of methods is both beneficial and comprehensible, although some of them did not believe it would improve the integration of simulation methods in the development process. This contradiction may be partly explained by the fact that no IT framework existed so far. Therefore, the general concept may have seemed more beneficial to them, whereas everything more closely related to applying the framework in the company, seemed far less beneficial in the absence of a real interface.

Regarding the initial question, both workshops showed that the framework concept is understandable in a short workshop. Nonetheless, the differences in the results between the two companies demonstrated how important prior process knowledge is in order to introduce the framework and transmit a more realistic experience of applying it in the company.

Therefore, especially workshop A showed that it is important to have a higher involvement in the project before the evaluation in order not to waste time on first documenting a process. One possibility to do so is to directly involve one of the industrial participants to be the moderator.

Furthermore, it could be beneficial to provide information material beforehand. Therefore, participants would start the workshop with prior knowledge about the framework concept, which might be beneficial. All these measures aim towards spending less time on explaining the toolbox and documenting processes and more time in the workshop on working with the actual toolbox.

Lastly, it could be important to tailor the workshops more to the needs of each participant. For that reason, it could be beneficial to gather information about each participant and put a focus on specific topic. For example, if a person from the manufacturing department is involved, it might be beneficial to put an emphasis on processes and methods related to manufacturing.

Especially when considering that most issues in the workshop were of formal nature, however, the results can be viewed as very positive and proof that it is worth continuing with further research on the concept. This encourages to continue the work on this holistic framework as it goes a step further than the current knowledge management and simulation management systems available on the market and discussed in the state of the art at the beginning of this paper.

## Further Work

Individual feedback showed that the participants wished to have goals in the user interface that are more general. Therefore, the research group intends to thoroughly analyze and revise all goals in the user interface again, before moving on with further extensions and evaluations of the framework with its current exemplary contents.

After the positive resonance on the concept, the most important milestone of the future is the integration of the toolkit of methods into a web-interface. It would then be possible to start further evaluations, even with company-specific interfaces. A prerequisite for that, however, is an implantation concept that includes briefings of users as the workshop



results show that those with the most knowledge about the context are those that profit the most from the framework. By also briefing non-experts, expert knowledge and methods can be shared via the framework and its IT equivalent. At this stage, the toolkit would be advanced enough to integrate it into an actual development process. Therefore, it would be possible to evaluate the integration of actual methods from the development process, as in workshop B, but on a far broader level.

Furthermore, it would be possible to evaluate how it can help to support and document along the development process and how well the framework is integrated into the process structure. An additional aspect for evaluation then is also the usability of the web interface. The evaluation results could then serve as a basis for realizing the system in a software solution that is ready to be applied in an industrial environment or sold as part of a commercial solution.

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