NordDesign 2022
August 16-19, 2022
Kgs. Lyngby, Denmark

System Modelling in the Problem-Solving Process - A Human Oriented Approach to the Use of MBSE in Problem-Solving Processes

Nikola Bursac[1], Albert Albers[2], Pascal Kull[2, 3], Simon Rapp[2], Ludwig Maul[4]

[1]Hamburg University of Technology (TU Hamburg), Am Schwarzenberg-Campus 1, 21073 Hamburg, Germany
nikola.bursac@tuhh.de
[2]IPEK – Institut für Produktentwicklung, Kaiserstraße 10, 76131 Karlsruhe, Germany
sekreteriat@ipek.kit.edu
pascal.kull@student.kit.edu
simon.rapp@kit.edu
[3]TRUMPF GmbH + Co. KG, Johann-Maus-Straße 2, 71254 Ditzingen, Germany
[4]Robert Bosch Power Tools GmbH, Max-Lang-Straße 40-46, 70771 Leinfelden-Echterdingen, Germany
ludwig.maul@de.bosch.com

Abstract

In order to combine fast thinking and slow thinking in product development, a new approach to system modelling in the problem-solving process is developed. For this purpose, five different system modelling use cases are analysed and their activities are attritubted to to one of seven types of activities of the universal SPALTEN problem-solving-framework. As a result, this human-oriented approach can help understand whether activites are more related to synthesis or analysis and guide decisisons at which points in the process the use of Model Based Systems Engineering (MBSE) makes sense.

Keywords: Model-Based Systems Engineering; Problem-Solving; SPALTEN-Methodology; Product Development; PGE - product generation engineering

1 Motivation

Value creation is being fundamentally transformed and market conditions are constantly changing. (Dumiterescu, Albers, Riedel, Stark, & Gausenmeiser, 2021) With future products and markets, the number of interfaces and dependencies will also increase, resulting in a greater need for cooperation. Development is taking place with an increasingly higher division of labor, interdisciplinarity and beyond company boundaries. (Muggeo & Wolters, 2019) In order to remain successful in the future, companies must adapt to the changing conditions. (Dumiterescu et al., 2021) The efficient handling of knowledge (Lohmeyer, 2013) as well as the correct use of methods in product development is a decisive factor for the future success of a company.
By using Model-Based Systems Engineering (MBSE) in product development, the goal is to represent complex systems in an understandable way. (Kleiner & Husung, 2016) For the profitable application of MBSE in the product development process, not only the language and the tool are required, but also the knowledge to apply them in a target-oriented manner. Because the application of MBSE itself is a complex (Weber, 2005) process and requires licensing rights for the software tools used as well as training for all users, both for modelling and for reading the models. This shows that the application of MBSE must also focus on the users.
A target-oriented usage of MBSE in product development and thus in problem-solving processes faces users with challenges. It must also be considered that engineering is still largely a creative activity of humans that should be supported. Even as a decision-making authority in human-technology collaboration, humans tend to be the leading authority. (Dumiterescu et al., 2021)

Kahnemann's model of fast and slow thinking (Kahneman, 2012) plays a decisive role here. As humans, we tend to use our fast, mostly associative thinking much more often than our more controllable slow thinking. Figure 1 shows such an example. On the one side a MBSE model, where slow thinking is needed to grasp it and on the right side a picture that describes the same object with the same components, but much easier and faster to understand. However, both systems are highly relevant for successful product development.

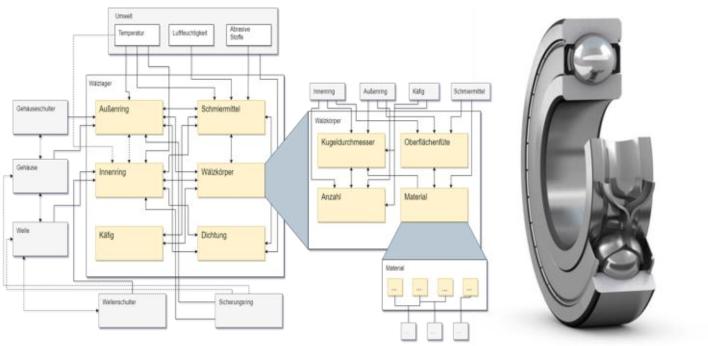


Figure 1. Kahnemann's model of thought shown in an exemplary MBSE model and picture of the same system

The following work is dedicated to the challenge of integrating aspects of system modelling in the problem-solving process in a way that the human being as the center of product generation development can act appropriately to the situation.

2 Basics and state of research

2.1 Model-Based Systems Engineering

Model-Based Systems Engineering (MBSE) is part of Systems Engineering (SE), an interdisciplinary approach to the methodical development of systems. MBSE is the visualization of a system and its results, which are generated from different activities. (Mandel, Böning, Behrendt, & Albers, 2021) This model thus serves to support the product development process and is intended to enable a continuous development process. (Andreasen, 1994) However, MBSE is currently primarily used for the formal modelling of system architectures. For the implementation, three parts known as the modelling triple are important: language, tool and method. All three aspects strongly interact with each other. (Matthiesen, Schmidt, Moeser, & Munker, 2014)

An added value of MBSE arises from the fact that developers can explicate and exchange their mental models by modelling in a defined way. For the exchange, several views can be derived from one complete MBSE model. Such a view describes a small part of the overall model that is relevant for the project but gives a better overview. By the interconnection of the elements, a change in one view also leads to a change in the entire model. This gives the advantage that models remain consistent and can serve as a basis for the exchange and explication of mental models. (Albers et al., 2014) However, this comes with the disadvantage that modelling becomes more complex and correspondingly more costly, since changes can only be made if they are conflict-free. In addition, the generic language and the high level of abstraction mean that MBSE is not yet so well established in applications. (Dumiterescu et al., 2021)

Even if in principle it would be possible to describe systems in all details with the help of MBSE tools, this is often not useful, since there are much more specialized and powerful tools for detailed descriptions. (Delligatti, Steiner, & Soley, 2014) The level of detail in the modelling must therefore be weighed up before each use. However, if interactions occur between different disciplines or tools where information regarding the system being modeled needs to be communicated, modelling usually makes sense.

Further hurdles in the introduction of MBSE in its current form are the lack of amortization concepts for the increased modelling effort, the insufficient user-friendliness of the IT tools and the poor integration into the existing engineering IT infrastructure. Hence, only a small group of people uses MBSE models but the greatest effect, namely better communication between different disciplines, is achieved when as many different groups as possible apply those models. It can be seen that MBSE has a high potential on the one hand, but also numerous hurdles on the other hand. (Dumiterescu et al., 2021) This also means that an approach for integrating system modelling into the problem-solving process is of particular importance in order to support users in the use of system modelling.

2.2 PGE - Product Generation Engineering

The model of PGE - Product Generation Engineering (Albers, Bursac, & Wintergerst, 2015) says, that product development is always based on a reference system Ri which is filled with different reference system elements. This serves as a basis for the development of a new product generation Gi. (Pfaff, Kubisch, Rapp, & Albers, 2021a)

Subsystems of a new product generation exclusively result on one of three types of variations. The Carryover Variation (CV) of a subsystem, where, if necessary, only the interfaces get adjusted. The Variation of Attributes (AV) is the development of a new subsystem by changing function-determining attributes while retaining the solution principle of the reference system element. And the Principle Variation (PV) were an alternative solution principle is used for the function of the reference system element. (Albers et al., 2019; Pfaff, Rapp, & Albers, 2021b) Accordingly, PGE helps with successful and rapid product development.

2.3 Innovation Process

In order to develop innovative and qualitatively new products and procedures, which differ noticeably from the comparative conditions (Hauschildt & Salomo, 2011) a broad orientation is required. By the obtained information and references, new products can be developed using different types of variation. In order to be able to make decisions, which projects will be further developed and focused on for market introduction, restrictions and concretions of the solution area are also needed. Due to the approach of screening a lot of information but also clearly narrowing it down, the innovation funnel as described by ALBERS (Albers et al., 2018) as well as CLARK and WHEELWRIGHT (Clark & Wheelwright, 1993) is also called an "innovation-focused" model. (Clark & Wheelwright, 1993)

2.4 Problem-Solving Process with SPALTEN

In product development, problems occur regularly. Often, they have to be solved in a short time due to development pressure. In such situations, a systematic problem-solving approach must be given a high priority. This means that engineers have to be equipped with the right tools for successful development management.

Different problem-solving strategies from a universal application with a low level of detail like the TOTE-scheme (Miller, 1960) to a technical application with a high level of detail like the REFA-Method (RFEA, 1985), many different problem-solving methods can be found. For this work the SPALTEN method is used because of its universal approach which is not limited to a special problem. (Albers, Saak, & Burkardt, 2002) It is based on various scientific studies on problem-solving and SE. By using SPALTEN, time and effort in a problem-solving process can be kept as low as possible and additionally an optimal solution can be achieved. (Albers, Burkardt, Mebodt, & Saak, 2005) SPALTEN (spalten = to split) is an acronym resulting from the names of the seven individual process steps.

- **S**ituationsanalyse
  Situation Analysis
- **P**roblemeingrenzung
  Problem Containment
- **A**lternative Lösungen
  Alternative Solutions
- **L**ösungsauswahl
  Solution Pre-selection
- **T**ragweitenanalyse
  Consequences Analysis
- **E**ntscheiden und Umsetzen
  Make Decision and Realisation
- **N**achbereiten und Lernen
  Recapitulate and Learn

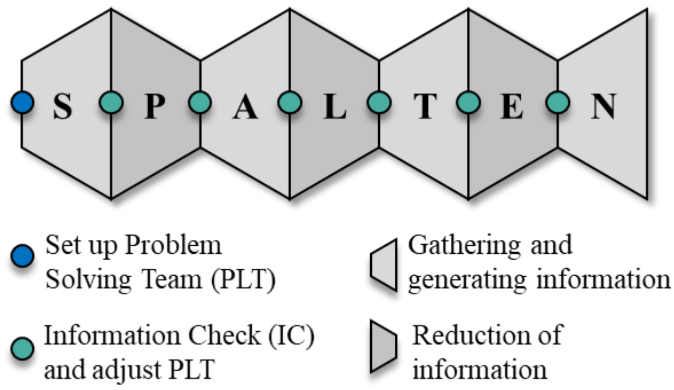


Figure 2. Breathing SPALTEN prozess

Each of these seven process steps can be assigned to one of two elementary processes of information processing, either gathering and generating information or reduction of information. (Albers et al., 2005; Albers, Reiß, Bursac, & Breitschuh, 2016) Figure 2 shows the periodic process of generating information and its reduction in the SPALTEN process, also called the breathing process.

Important for the SPALTEN process is the so-called Information Check (IC) the continuous checking of the information between the individual steps. This involves analysing whether the information base is sufficient to carry out the next step or whether, for example, additional information is still needed and yet another process step is chosen.

The establishment of a problem-solving team (PLT) and the continuous review and adjustment of the PLT are also essential elements of the SPALTEN process. This is important because different activities require different competencies that can be contributed by different people. Consideration of the problem-solving team plays a critical role in the success of a process. For instance, creative people can offer a valuable contribution in generating alternative solutions. Thus, it is continuously reviewed whether the composition of the PLT meets the requirements of the current activity or whether additional experts are needed. (Albers et al., 2016)

During the problem-solving process, ideas are continuously collected. To ensure that they don´t get lost, they are stored in the Continuous Idea Store (KIS). It is used to systematically generate and store solution ideas from the problem-solving team. In this way, every participant can access the entire solution space at any time. (Albers et al., 2016)

A reasonable cost-benefit ratio is important in problem-solving. This can refer both to the scope of the individual steps and - if reasonable and sufficient - to the only partial execution of the process. A return to earlier steps is also possible. (Albers & Braun, 2011)

2.5 Human-oriented modelling

Increasing dependencies within projects due to different disciplines and stakeholders require companies to rethink their way of work. (Dumiterescu et al., 2021) The human being has to be seen as part of a socio-technical system. (Ropohl, 2009)

In reality, employees are expected to contribute to the work process in a more self-organized manner with competencies such as communication and cooperation skills, but also creativity and flexibility. (German Federal Ministry of Education and Research (BMBF), 2020) However, this is hampered by the lack of structures for the use of MBSE in the problem-solving process. Therefore, the human-technology division of labor must be designed in a way that better decisions can be taken faster through collaboration in the socio-technical system. (Dumiterescu et al., 2021)

Humans, as the center of product development and the problem-solving process, are required to contribute their creativity to development in order to foster innovation. In doing so, developers are challenged by diverse issues, such as the increasing interdisciplinarity of projects. (Albers, Maul, & Bursac, 2013)

Integrating people into the problem-solving process seems to be the key to solving the challenges, while new methods and approaches in engineering like MBSE need to be even more human-oriented to be implemented in product development

3 Research questions and Research method

Currently, there are still difficulties in applying MBSE in problem-solving processes. It is often not clear to users whether and when the use of system modelling is worthwhile and how models should be used. (Dumiterescu et al., 2021)

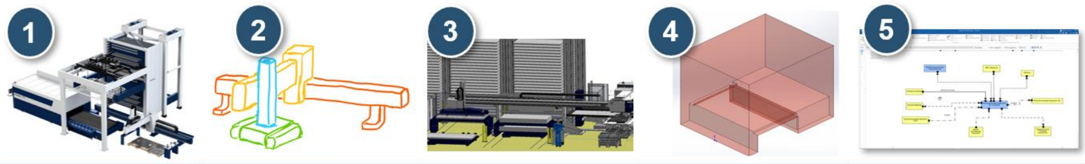
- At what point in product development processes are MBSE models used and what insights can be gained?
- How can the observed use of MBSE models be mapped into problem-solving activities according to SPALTEN?

The research method of this work is based on the Design Reasearch Methodology according to BLESSING. (Blessing & Chakrabarti, 2009) To answer the first question, descriptive study one, five system modelling use cases from automation development at TRUMPF as well as research activities as part of the research project MoSyS - Human-Oriented Design of Complex Systems of Systems are analysed. The model analysis and synthesis activities are mapped to the steps of the problem-solving method SPALTEN and the purpose of each use is examined. To answer the second question, in the Prescriptive Study the observed usage and lessons learned are used to derive and map an approach to MBSE model usage. This is to show where and to what extent system modelling can be appropriately put to use in the problem-solving process so that the user can derive the maximum added value from its use.

4 System modelling in problem-solving processes

In order to gain insights into the use of MBSE models, various product development processes from different phases with different boundary conditions, as shown in Table 1, were analysed. All use cases were analysed using the SPALTEN problem-solving method. In this observation, the use of MBSE models is divided into the analysis and synthesis activities.

Table 1: System modelling use cases in overview.



	Product portfolio analysis	Concept Development	Distrubance contour model	Construction space modelling	Modular architecture modelling
Team					
Duration	5 Weeks	17 Weeks	2 Weeks	10 Weeks	12 Weeks
Phase	Planning	Concept	Development	Design	Concept

In the first use case, it is found that the synthesis of MBSE models works well in the information reduction steps. In this case, a rough model was created in problem containment, which was further refined in solution pre-selection and making decisions and realisation. Synthesis of MBSE models already in the situation analysis or alternative solution turned out to be problematic in use case five. It led to many discussions on details, project delays and finally even to the termination of the project. But also in use case three it was shown that synthesis in the recapitulate and learning was too late and also led to problems, because information had to be dragged on which caused project delays of subsequent projects, as well as loss of information.

Due to the lack of MBSE models for analysis, in the first use case the model created up to that point was only analysed in the consequences analysis. If models already existed for analysis, such as in use cases two and four, it became apparent that the models were used for analysis purposes, especially in the initial phases of situation analysis, problem containment and, in some cases, alternative solutions. For analysis in the consequence analysis, the newly created models were then used and partly compared with reference models. Table 2 shows the insights gained from the use cases, arranged according to problem-solving steps.

Table 2: Analysis and synthesis of MBSE models in the activities of problem-solving according to SPALTEN

S	• Analysis of different and many MBSE models and sources seems useful • Lack of existing MBSE models does not have to stop product development • Synthesis of an MBSE model can lead to problems
P	• (Early) narrowing down solutions essential for meaningful use of MBSE • Structuring of large quantities by fast thinking • Analysis of MBSE reference system can help with structuring • First (rough) synthesis
A	• Recommended: further research without synthesis of MBSE models • Quantity and quality of information unsuitable for building MBSE model • Creative phase / visualization helpful • Synthesis of MBSE model can lead to problems
L	• Structuring / pre-selection of solutions by fast thinking • Creation or extension of MBSE model
T	• Analysis and synthesis to improve models (iterative) • Visualizations helpful
E	• Decision on pre-selection based on consequence analysis • Synthesis / completion of MBSE models
N	• Analysis of MBSE models for learning • Pure synthesis of models in this phase leads to problems and reduced quality in the problem-solving processes

5 Approach to system modelling

5.1 Basic properties

The combination of the innovation funnel and the breathing SPALTEN process serves as the basis for the integration of system modelling in the problem-solving process. The area spanned by this breathing funnel gives an indication of the opened solution space, which becomes smaller in each information reduction step. By a following information generating process step the previously concretized area is expanded again.
The use of MBSE models, which is divided into analysis and synthesis activities, is strongly dependent on the solution space as well as on the type of process step.

5.2 MBSE in the problem-solving process

Situation Analysis

The main activity in situation analysis is to gather and generate information for the problem-solving process. Existing products can serve as reference systems. In the observed processes, it can be seen that situation analysis can be performed both with and without pre-existing MBSE models. However, the availability of MBSE models can be very helpful for their analysis.

For the variety and large amount of sources and new approaches, an open and creative mindset is important. The early focus on details can lead to different perspectives, divergent opinions and discussions, thus hindering the pursuit of new approaches. In addition, the synthesis of MBSE models slows down situation analysis and thus prevented quick and effective action which is harms a creative problem-solving process.

Key observations:

- Information generating: analysis of existing MBSE models can be interesting and helpful throughout the situation analysis process
- Variety of different sources creates a good basis for subsequent process steps
- Dealing with large amounts of often non-specific information requires fast thinking and a view of the big picture

Problem Containment

Important in problem containment is an initial reduction to essential content, especially in open, comprehensive problem-solving processes. Reduction of information is of great importance to keep the process effective. Due to the large amount of content, different maturity levels of ideas and varying data situation, a fast approach is suitable. If available, an analysis of existing MBSE models from R_i, can help with problem containment. After narrowing down, building a rough MBSE model can be useful to have a common starting point for subsequent problem-solving steps in G_i.

This approach is partly due to the wide range of possibilities that remain at this stage in the problem-solving process, and partly due to the wide openness of the solution spaces, some of which cannot be represented at all in detailed models.

Key observations:

- Large amount of information requires fast approach to clustering and initial narrowing down
- Analysis of existing MBSE models can help with problem containment
- Synthesis of rough MBSE → model information usually not suitable for detailed models
- New findings and boundary conditions must be incorporated into the narrowing down process

Alternative Solutions

The alternative solutions as an information-generating process step has as its main task the creation of new problem-solutions. Here, the analysis of existing models from R_i or G_i can be useful in combination with creative ideas. However, the synthesis of MBSE models through the detailed linking of individual elements is not suitable, because work and thinking are only done within the framework of the previous model. This would severely limit creativity and does not necessarily allow open-ended work. Also, parallel work by building models during alternative solutions phase slows down the process.

Key Observation:

- Analysis of MBSE reference systems can help in solution finding
- Creative and open-ended process
- Creating many possibilities → spanning the space as wide as possible requires fast and creative thinking

Solution Pre-selection

Solution pre-selection is about narrowing down further and making a pre-selection. This is why the process step is renamed from solution selection to solution pre-selection.

In order to work with the pre-selection in the following steps and to be able to check it, the modelling, means the synthesis of MBSE models into the G_i, is useful. A lack of models can have an negative impact on the qualitative execution of the scope analysis as well as the decision and implementation.

Key observations:

- Pre-selection of solution concepts
- Synthesis of MBSE models, useful especially for consequence analysis
- Parts of old models can be used to develop new models

Consequences Analysis

In the consequence analysis, a model from G_i normally created during the solution pre-selection, is used to identify risks and improvement potentials. The consequence analysis is often an iterative approach, were analysis and synthesis activities are mixed.

For the presentation to stakeholders, the visualization of models and analyses is essential to quickly provide understanding for concepts created. It is also possible to combine and enrich already existing models from R_i with new models from G_i, for example to perform an analysis in the overall concept.

Key observations:

- Mix of analysis and synthesis activities
- Use of created models
- Extent and quality of analysis dependent on methods, time spent, models, and effectiveness of solution pre-selection

Make Decision and Implement

Make decision and implement is an information-generating problem-solving step. Based on the scope analysis, a decision is made on the solution pre-selection which is confirmed or rejected. If it is confirmed, the solution will be implemented. For this purpose, the MBSE models are further developed and completed and stored in Gi. So that the model can be used for further problem-solving processes as well as the following Recapitulate and Learn process step.

Key observations:

- Confirming or rejecting the solution pre-selection
- Further developing and completing the MBSE model

Recapitulate and Learn

Recapitulate and Learn is characterized by analysis of G_i and small synthesis steps. The step should not be used for pure synthesis, as the creation of MBSE models in earlier phases leads to smoother transitions to subsequent problem-solving processes, thus also avoiding loss of information.

Recapitulate and Learn is more suitable for analysing the information gained and deriving conclusions from it.

Key observations:

- Mixture of analysis and synthesis with a stronger analytical character
- Use of created MBSE models for drawing knowledge for the following processes

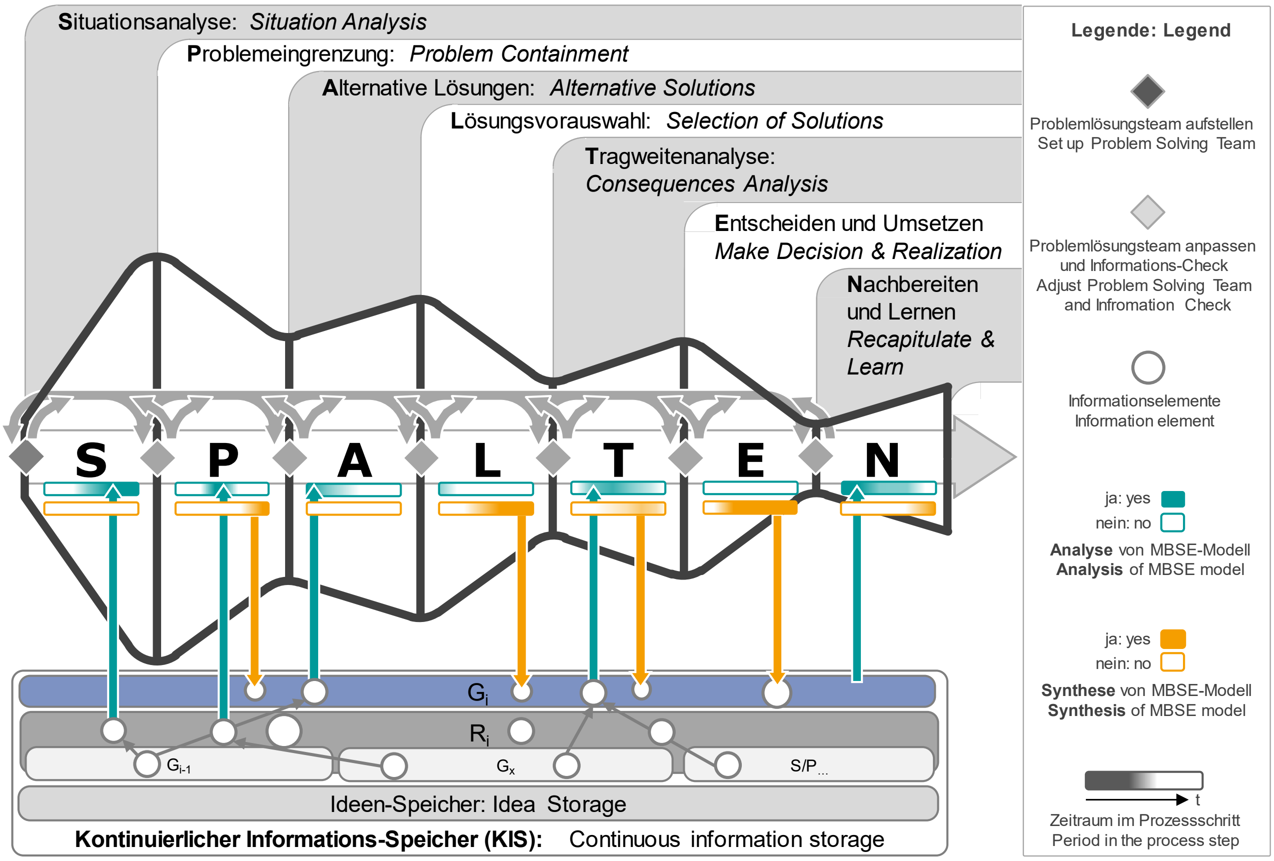


Fig. 3. Graphic of the human-oriented approach for the use of MBSE in the problem-solving process.

Users have a large influence on how MBSE is used in the problem-solving process. Creating MBSE models is time-consuming and requires trained staff. Therefore, the effort-benefit ratio must be weighed. Creating MBSE models too late can lead to loss of information or delays in subsequent processes. Synthesizing MBSE models too early can lead to slowdown and lack of problem identification in the process, as creative competencies of users are suppressed. Also, post-modelling of already existing reference systems is not necessarily required in advance. Figure 3 summarizes the use of MBSE models to facilitate their use by users.

6 Conclusion

The work primarily extends the SPALTEN problem-solving approach by adding a layer for the analysis and synthesis of MBSE models in the course of a solution process. This facilitates users to apply MBSE models in an appropriate and accordingly profitable scope. Furthermore, the SPALTEN problem-solving approach is extended by two additional elements. First, the visualization of the solution space, which, in addition to the knowledge of the Breathing Process, provides the user with feedback on the amount of information and thus the aspired MBSE usage. Second, the extension of KIS to a continuous information storage with reference system, reference system elements and information elements which in turn are of great relevance, as they form the basis for the use of MBSE. All this leads to a human-oriented approach to the use of system modelling in the problem-solving process, which entails a wide range of application potential due to its variety of system modelling use cases on which the insights are based.

This approach may be suitable for companies with and without experience in the use of MBSE, as well as research and education. In addition, the goal of the approach is to facilitate the use of MBSE across disciplines. Thus, users of other engineering sciences as well as persons outside of engineering sciences shall be facilitated in the use of MBSE. This broad applicability has to be validated by additional system modelling use cases from other companies, industries and with different users. In addition to the applicability, the diversity of the companies and the tools being used should also be considered.

The influence of PGE on the use of MBSE models especially in later stages of development, for example during series production, as well as the use of MBSE models beyond development are also important milestones in the further evolution of the presented approach for system modelling in the problem-solving process and may lead to improved habits in the use of MBSE.

Acknowledgement

This article was written as part of the research project MoSyS - Human-Oriented Design of Complex Systems of Systems. This research and development project is funded by the German Federal Ministry of Education and Research (BMBF) within the “The Future of Value Creation – Research on Production, Services and Work” program and managed by the Project Management Agency Karlsruhe (PTKA). The authors are responsible for the content of this publication.

Reference List

Albers, A., & Braun, A. (2011). A generalised framework to compass and to support complex product engineering processes.

Albers, A., Burkardt, N., Mebodt, M., & Saak, M. (2005). SPALTEN PROBLEM SOLVING METHODOLOGY IN THE PRODUCT DEVELOPMENT.

Albers, A., Bursac, N., & Wintergerst, E. (2015). Product generation development– importance and challenges from a design research perspective.

Albers, A., Heimicke, J., Walter, B., Basedow, G., Reiß, N., Heitger, N., et al. (2018). Product Profiles: Modelling customer benefits as a foundation to bring inventions to innovations, 253–258.

Albers, A., Matthiesen, S., Bursac, N., Moeser, G., Schmidt, S., & Lüdecke, R. (2014). Abstraktionsgrade der Systemmodellierung. von der Sprache zur Anwendung.

Albers, A., Maul, L., & Bursac, N. (2013). Internal Innovation Communities from a User's Perspective: How to Foster Motivation for Participation.

Albers, A., Rapp, S., Spadinger, M., Richter, T., Birk, C., Marthaler, M., et al. (2019). The reference system in the model of PGE: proposing a generalized description of reference products and their interrelations.

Albers, A., Reiß, N., Bursac, N., & Breitschuh, J. (2016). 15 Years of SPALTEN Problem Solving Methodology in Product Development.

Albers, A., Saak, M., & Burkardt, N. (2002). Gezielte Problemlösung bei der Produktentwicklung mit Hilfe der SPALTEN-Methode.

Andreasen, M. M. (1994). Modelling—the language of the designer.

Blessing, L., & Chakrabarti, A. (2009). DRM: a Design Research Methodology.

Clark, K. B., & Wheelwright, S. C. (1993). Managing new product and process development.

Delligatti, Steiner, & Soley (2014). SysML distilled: Upper Saddle River.

Dumiterescu, R., Albers, A., Riedel, O., Stark, R., & Gausenmeiser, J. (2021). Advanced System Engineering: Wertschöpfung im Wandel Engineering in Deutschland - Status quo in Wirtschaft und Wissenschaft.

German Federal Ministry of Education and Research (BMBF) (2020). *Vorhabensbeschreibung - Verbundprojekt "Menschorientierte Gestaltung komplexer System of Systems".*

Hauschildt, J., & Salomo, S. (2011). Innovationsmanagement: Die 6 Phasen von der Idee zur Umsetzung.

Kahneman, D. (2012). Thinking, Fast and Slow.

Kleiner, S., & Husung, S. (2016). Model Based Systems Engineering: Prinzipien Anwendung Beispiele Erfahrung und Nutzen aus Praxissicht. *Tag des Systems Engineering*, 13–22.

Lohmeyer, Q. (2013). Menschzentrierte Modellierung von Produktentstehungssystemen unter besonderer Berücksichtigung der Synthese und Analyse dynamischer Zielsysteme.

Mandel, C., Böning, J., Behrendt, M., & Albers, A. (2021). A Model-Based Systems Engineering Approach to Support Continuous Validation in PGE - Product Generation Engineering.

Matthiesen, S., Schmidt, S., Moeser, G., & Munker, F. (2014). The Karlsruhe SysKIT Approach: A Three-Step SysML Teaching Approach for Mechatronic Students.

Miller, G. A. (1960). Plans and the structure of behavior.

Muggeo, C., & Wolters, R. (2019). Model-based Systems EngineeringBSE_de: MBSE und PLM kombinieren und so modernste Entwicklungsprozesse implementieren.

Pfaff, F., Kubisch, J., Rapp, S., & Albers, A. (2021a). Characterizing Product Development Processes in Start-ups: an Empirical Study.

Pfaff, F., Rapp, S., & Albers, A. (2021b). MODELLING AND VISUALIZING KNOWLEDGE ON THE REFERENCE SYSTEM AND VARIATIONS BASED ON THE MODEL OF PGE - PRODUCT GENERATION ENGINEERING FOR DECISION SUPPORT.

RFEA (1985). *REFA Methodenlehre des Arbeitsstudiums.: Teil 3, Kostenrechnung, Arbeitsgestaltung* (7. Auflage). München: Caerl Hanser Verlag.

Ropohl, G. (2009). *Allgemeine Technologie : eine Systemtheorie der Technik* (3. Auflage): KIT Scientific Publishing.

Weber, C. (2005). What is "complexity"?.