Development of an Implementation Proposal in Systems Engineering Using TenneT as a Case Study: An Integrated GAP Analysis of Current Processes

Master Thesis

for the award of the academic degree “Master of Science (M.Sc.)” in the degree program Industrial Engineering of the Faculties of Electrical Engineering and Computer Science, Faculty of Mechanical Engineering and the Faculty of Economics and Business Administration of Leibniz Universität Hannover

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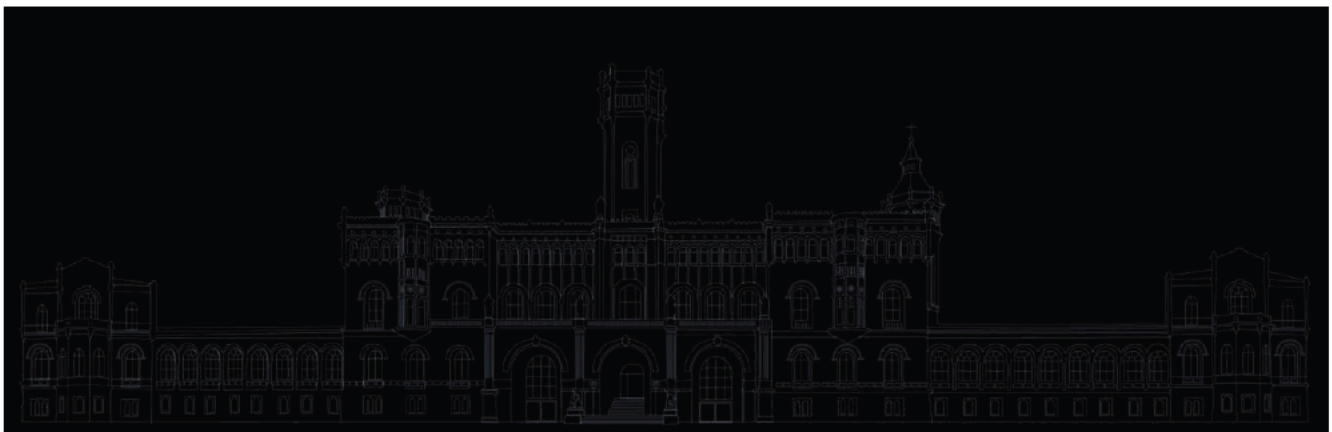

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1 Introduction and Motivation

The further development of modern systems in industry requires a deeper understanding and handling of system complexity. Especially in technology-intensive industries, companies are increasingly reaching their limits when it comes to efficiently developing and managing complex technical systems. Mechanical systems are developing into even more complex systems with increasing challenges. In particular, the overarching need for coordination requires new approaches. In this context, there is an increasing demand for structured approaches to manage this complexity (Bretz et al., 2020, p. 101). A promising approach to meeting these challenges is the use of systems engineering (SE). As an interdisciplinary approach, SE is becoming increasingly important for systematically supporting companies in the development of complex systems. However, a standardized methodology for introducing SE is lacking, therefore companies face specific challenges (Inkermann, 2021, p. 2642). In particular, the use of SE at TenneT presents challenges because the existing processes are not sufficiently aligned with SE, resulting in a lack of a unified structure. This thesis specifically examines the successful realization of a general implementation approach for SE. Such an approach would benefit not only the company but also various industries.

Industries with high regulatory requirements and increasing complexity stand to benefit from such an approach. A current example of this is the offshore renewable energy sector, which is characterized by high degrees of standardization and increasing complexity. This demonstrates the need for structured approaches to generate cross-project synergies. A review of the existing literature has shown that there are no established implementation approaches for the offshore sector, so there is a clear research gap here. The following two research questions can be derived from this:

1. What challenges arise when implementing systems engineering?
2. How can companies implement a systems engineering approach in practice?

To answer the research questions, an introduction to the SE Approach according to ISO/IEC/IEEE 15288:2023 is given at the beginning. The research methodology is based on the Design Science Research approach by Schoormann et al. (2024).

As part of this master's thesis, a comprehensive literature review, expert interviews and a survey are conducted to gain clear insights. Based on the collected data, an artifact in the form of a process model is developed. Subsequently, the model is presented to a focus group to evaluate its practical feasibility. The objective of the completed process model is to enable companies in different industries to systematically identify and gradually implement missing SE processes.

The structure of the thesis is shown below. First, the specific approach of the methodology is explained in order to illustrate the results based on it. Second, the specific methodology is explained before the findings are presented. After a comprehensive literature review, the results of the expert interviews and the survey are integrated to obtain a comprehensive picture of the challenges and solutions. Based on this, a first draft of the process model is developed. With the subsequent gap analysis, the goal is to identify company-specific deficits to derive further recommendations for action. In conclusion, the results and limitations of the work were presented in the context of a discussion, providing an outlook on future research questions. The aim of this work is to further develop existing SE implementations in order to offer companies a practical implementation option.

The present thesis has been written in English in order to ensure maximum accessibility to an international academic audience. Nevertheless, data collection – encompassing expert interviews, a survey, and a focus group discussion – was conducted in German to enhance response accuracy and validity by allowing participants to express themselves in their native language. The analysis method, with all coding and interpretation conducted in German for consistency. However, to align with the language of the thesis, only the final category labels have been translated into English. Original German excerpts are provided in the appendix where necessary to ensure transparency. Furthermore, the program DeepL was used as a translation tool. In addition, DeepL Write and ChatGPT were used as a formulation aids, but explicitly not for writing texts. In addition, artificial intelligence, in particular OpenAI's ChatGPT, was used to generate structural ideas and support a deeper understanding of the topic.

7 Conclusion and Outlook

The aim of the thesis was to identify the main challenges and possible solutions for a successful implementation of SE and to derive a practical implementation proposal from this. The central research questions to be answered are what obstacles companies face when introducing SE and how a structured implementation approach for practical application can be designed based on this.

To answer this question, a combination of extensive literature research, expert interviews, a survey and a final focus group discussion was conducted. A practice-oriented process model with 6 phases was developed to support companies in the context-specific implementation of SE and the adaptation of existing structures. The analysis showed that the introduction of SE is not only a technical challenge, but that organizational, procedural and cultural factors also play a decisive role. Key barriers identified included resistance to change, insufficient standardization, a lack of training measures and a lack of support from management. The comparison of the empirical results with the existing literature makes it clear that the implementation of SE requires a profound change in the company.

The developed process model is based on an iterative approach with recurring feedback loops. A completely standardized approach was deliberately avoided in favor of one that allows sufficient flexibility and adaptability to company-specific requirements. The step-by-step approach enables continuous evaluation and, if necessary, adaptation of the implementation, which increases acceptance within the organization and promotes sustainable introduction in the long term. The results of the work are both scientifically and practically relevant. The model developed provides companies that want to introduce SE with a structured orientation that they can adapt individually. The study confirms that successful implementation does not only result from the introduction of new processes and methods, but also from the targeted involvement of employees and a step-by-step change in corporate culture initiated by management. These findings directly answer the research question: The introduction of SE therefore requires not only technical integration, but also specifically initiated changes to structures, processes and corporate culture, which must be actively controlled by management. The developed model offers a practical solution that can be adapted to the specific requirements of the company.

On the basis of this work, new research questions can be derived that can be explored in more depth in future scientific studies and in practice. The present study identifies the scalability of the process model as an aspect of particular relevance. Future studies could address the question of the extent to which the model can be adapted for smaller or larger companies and applied in practice. In this context, the inclusion of different

industries is crucial to create a well-founded knowledge base. Another aspect is the identification of specific monitoring systems, such as existing maturity models, to enable a consistent evaluation of individual processes. Furthermore, an in-depth analysis of additional processes not considered so far would be necessary to ensure a more comprehensive understanding of the implementation and maturity of SE practices. Furthermore, a cross-industry analysis could provide valuable insights, particularly with regard to specific regulatory requirements. Since this work is primarily a snapshot, it is of great scientific and practical interest to see how the implementation of SE based on this process model will develop in the coming years.

To optimize implementation in the long term, continuous monitoring by SE experts should be established. KPIs could be defined to objectively measure the maturity and effectiveness of SE implementation. Furthermore, there is an increasing demand for a stronger scientific engagement with SE in Germany. The funding of interdisciplinary research collaborations between universities and companies would be a further step towards strengthening the scientific foundation of SE and at the same time developing practical solutions for the economy. Furthermore, it can be assumed that with increasing digitalization, new requirements for SE methods will arise that have not yet been considered in this work. A promising research field in this context is the integration of SE with data-driven technologies, especially with artificial intelligence, to automate decision-making processes and enable efficiency gains.

In summary, this work provides a well-founded analysis of the challenges and success factors of SE implementation and provides a practice-oriented model. In addition, promising research perspectives are highlighted that can help to further optimize the implementation of SE and adapt it to future requirements.