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Data-driven decision support in the design and controlling of systems engineering transformation: a maturity model

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ABSTRACT: Challenges of increasing system complexity and the need for interdisciplinary collaboration are prompting companies to reorganize towards Systems Engineering (SE). As part of the implementation of large-scale transformation programs, transformation progress is of great interest to management and employees involved. Existing maturity models lack measurable variables and reliable forecast. For this reason, a maturity model for evaluating SE Transformation is developed, that builds on quantitative metrics and enables an overarching view on transformation considering cultural aspects. Literature-based criteria for evaluating SE Transformation lay the foundation for measures and referenced metrics and indicators. Due to its data-centricity, the model presented enables a more comprehensive, fact-based decision-making basis for the design and steering of SE Transformation programs.

KEYWORDS: systems engineering (SE), complexity, decision making

1. Introduction

The increasing complexity of modern cyber-physical systems requires both interdisciplinary and effective collaboration across specialist areas and system boundaries in order to overcome the current challenges of engineering. Systems Engineering (SE) is an engineering approach that focuses on precisely these aspects: At its core is the principle that the design of complex systems, such as those in the automotive industry, can only be successful in a united, interdisciplinary team (Gräßler & Oleff, 2022). For this reason, numerous companies are introducing SE in large-scale transformation programs to gain a competitive edge and be robustly positioned for future increases in system complexity. Current challenges and events in automotive industry, such as VWs Joint Venture with Rivian, show that a change of paradigms is necessary in an industry that has been characterized by hardware engineering for decades, and requires a fundamental change and rethinking in engineering vehicles (Boes, 2024). Systems Engineering comprises an approach to execute this shift of paradigm at large car manufacturers but requires high investments in transformation programs (Davey, 2020).
Due to these high investments, the transformation progress is of great interest, both for the company management and for the employees involved in the transformation. While the content-related progress is of great interest from the perspective of the project participants, the overall progress, including the sustainable anchoring of the change, is of interest from a higher-level company perspective. In order to provide this overview, the basics of organizational development must be used in addition to subject-specific, content-related maturity models for SE.
With this motivation, this study derives quantified measures, metrics and indicators based on research work and transfer them into a model for assessing the maturity of SE Transformation. In the following first the scientific approach and essential state of the art is presented. In section four measures, metrics and indicators of are derived which form the basis for the maturity model presented in section five. The results of this research are critically reflected in section 5 and summarized in section six.

2. Methodology

To achieve this research objective, a scientific approach is taken in four steps. First, based on a literature review of the state of the art, related work is identified, examined and the research gap to be addressed in this research is worked out. Ongoing, quantified measures are derived from criteria addressed in existing work for evaluating SE Transformation, which are converted into metrics and indicators. These form the basis for the development of the maturity model for evaluating SE Transformation, which comprises a comprehensive model, including a descriptive information model. In developing the model, the focus is narrowed to the organisational perspective, i.e. the consideration of roles, responsibilities and management involvement, for example. Financial aspects are essential in transformation steering, as they are in programme management, but are not yet taken into account at this stage. Established methods such as Earned Value Analysis (EVA) can be used to complement the model presented here. Finally, the maturity model is critically discussed and reflected based on authors experience over decades in automotive industry and research. Potentials for the application of the maturity model are derived from the findings of the discussions and further research fields are presented.

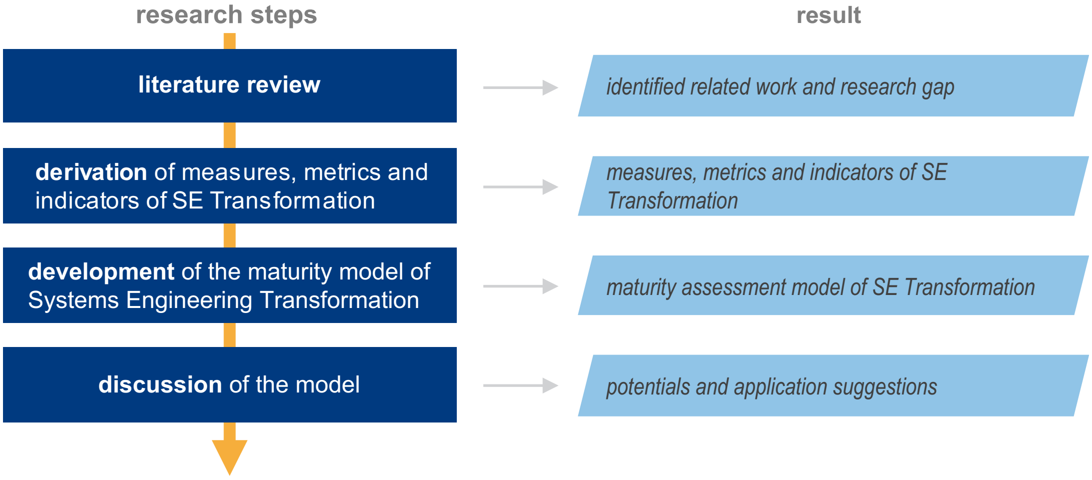

Figure 1. Scientific approach of this research

The literature review is conducted to identify and sharpen the research gap and questions of this research work according to PRISMA (Page et al., 2021). Based on fundamental work, a final search string is identified (see figure 2) and executed in the scientific online databases SCOPUS, Web of Science and IEEE explore. Including 7 additional records, a total of 32 records is identified, including 8 duplicates. Within screening, titles, authors key words and abstracts are reviewed for relevance, resulting in 11 eligible records. These selected papers are analyzed in complete and relevant approaches are identified by defined selection criteria (focus is on Systems Engineering transformation / implementation, organizational change is considered, transformation progress is assessed, criteria for transformation assessement are proposed, model or method for transformation assessment / monitoring is proposed, a quantitative / measureable approach is proposed). All approaches that fulfil at least one of these criteria are included. Finally, nine research works are included.

("introduction of Systems Engineering" OR "implementation of Systems Engineering" OR "Systems Engineering Transformation") AND ("measurement" OR "assessment" OR "progress")

Figure 2. Executed search string

3. State-of-art

Systems Engineering (SE) comprises an engineering methodology for complex technical systems (Gräßler & Oleff, 2022). Based on systems thinking, defined processes and roles the overall target is to achieve an interdisciplinary optimum within a predefined time and cost frame (Gräßler, 2015). One main focus of SE is to consider the interaction of multiple disciplines and consolidating different perspectives to an consistent, overall system understanding (Gräßler & Oleff, 2022). The implementation of SE especially requires tailoring of a selected approach (such as (Department of Defense, 2022; INCOSE, 2023; NASA, 2007)) to the organization's needs and project conditions (Gräßler & Oleff, 2022). Established SE approach lay different focal points of main aspects and foundations. Graessler and Oleff consolidate three core elements, systems thinking, engineering methodology including process landscape and SE roles, and three enablers, tailoring, methods and modelling, for SE application (Gräßler & Oleff, 2022). As an example, predefined role models, such as (Graessler et al., 2019; Graessler et al., 2021; Sheard, 1996), can be tailored to project scoping and resources (Graessler et al., 2022).

3.1. Maturity models of Systems Engineering

Wilke et al. present a systematic literature review on maturity models in SE and identify four key maturity models (Wilke et al., 2022). White points out the necessity of a maturity model in SE and suggests six essential milestones (White, 2016). Cusick adapts the foundations of the Capability Maturity Model Integration (CMMI) and presents a SE specific approach (SE-CMM, originally comprised by (Bate et al., 1995)) focusing on the assessment of SE process implementation (Cusick, 1997). The third maturity model identified is by Cornu et al. and offers a maturity assessment for the development of company specific SE processes (Cornu et al., 2012). In addition, Kasser and Frank comprise a maturity model to assess the capabilities and competence of systems engineers (Kasser & Frank, 2010). Based on this research, Wilke et al. present a maturity model for the implementation of SE based on three assessment dimensions and twenty fields of action (Wilke et al., 2022). In addition different authors have proposed further developments of maturity models with specific focal points (see, for instance, (Bretz, 2021; David D. Walden et al., 2015; S.-O. Schulze & Steffen, 2018; Sheard & Lake, 1998; Steffen et al., 2017; Widmann, 1998)).

3.2. Systems Engineering ransformation

The introduction and application of SE requires changes in existing engineering approaches in organizations (Graessler & Grewe, 2024). These changes affect not only technical processes and applied methods, but also aspects of cooperation, corporate culture and organizational structure (Arnold & McKinney, 2022; Graessler & Grewe, 2024). SE Transformation refers to the fundamentals of organizational development and change (Graessler & Grewe, 2024). Multiple authors therefore point out the importance of a structured transformation approach and change management (Bretz, 2021; Heihoff-Schwede et al., 2019; Wilke et al., 2022). Within transformation steering activities of planning, controlling and monitoring are mainly important (Hartwich, 2014; Moedritscher & Wall, 2022). For that reason, reliable indicators for SE Transformation design and steering (Hartwich, 2014) are required.

3.3. Measures and metrics

The international standard ISO/IEC/IEEE 24765 (ISO/IEC/IEEE 24765:2010) defines central terms of systems and software engineering, which are used as the basis for this work:
A measure is the value of a variable from raw data or a quantitative quantity that is directly derived as a 'result of measurement' (ISO/IEC/IEEE 24765:2010). This definition assumes that the measure is collected directly from the real, observable environment and mapped in a variable. A measure is the foundation on which metrics are based. An example of a measure is the number of employees involved in SE Transformation.
As defined in the international standard, a metric is formed from one or more measures to evaluate specific aspects of a system (ISO/IEC/IEEE 24765:2010). Metrics summarize measures into an assessable quantity and often provide a comparison to defined standards or targets and therefore describes the required algorithm or formula (Texel, 2013). For example, a metric can express the level of tool availability required for SE through the ratio of available tool licences and the number of required tool users.
Indicators are specific key metrics that serve as signals or indications of a system's relevant status or performance (ISO/IEC/IEEE 24765:2010). They are used to identify developments or trends and to highlight a need for action. To make this possible, indicators require a baseline in addition to a contextual content (Texel, 2013). One indicator could be the number of staffed SE roles as a signal for the

completion of implementation of SE methods in terms of SE Transformation progress evaluation. The required baseline could be the completion of implementation in a reference project at the same time passed in the project.

3.4. Research gap and research questions

Based on the previously presented selection criteria, the identified approaches are assessed, and a research gap is identified. While existing maturity models provide a foundation for assessing the implementation of SE at the content level, they lack an overarching transformation view. Some approaches, for example (Bate et al., 1995), concentrate primarily on the maturity of the SE processes. Furthermore, existing models provide assessment criteria or milestones that are primarily evaluated qualitatively according to a defined scheme of levels, such as (Bretz, 2021) or (Wilke et al., 2022), but were lacking for defined quantitative measures. Currently, there is a gap in terms of the relationship between maturity criteria and measurable variables in SE Transformation. In addition, the existing maturity models lack a reliable baseline for a reliable assessment of progress and its forecast. Consequently, this research aims to address this gap by answering the following research questions (RQ):

RQ1: How can existing definitions of measures, metrics and indicators be applied to measure SE Transformation?

RQ2: How can applied indicators be evaluated and interpreted to assess the SE Transformation progress?

RQ3: How can a forecast of SE Transformation be conducted and used as decision basis for the design and steering of SE Transformation?

4. Measures, metrics and indicators of SE Transformation

The defined relationship of measures, metrics and indicators (ISO/IEC/IEEE 24765:2010) is used as a foundation for a SE specific derivation for SE Transformation assessment. Based on the information model by Texel (Texel, 2013), the relationship is illustrated using a selected example out of SE Transformation (see Figure 3): Measures quantify aspects of the SE Transformation (ISO/IEC/IEEE 24765:2010). For example, the number of staffed SE roles as well as the number of SE roles defined in organizational structure can be measured. The metric ‘role staffing’ summarizes these two measures and puts them in a common context including the required formula (according to ISO/IEC/IEEE 24765:2010). As the final fact of interest in terms of SE Transformation, namely the ‘completion of staffing of SE roles’, is not a quantifiable entity, an indicator is required. The number of ‘staffed SE roles’ aligned with the baseline of an ‘estimation’ for the current time, based on a pilot project, serves to indicate whether the completion of staffing is proceeding in accordance with the planned schedule or in a manner that deviates from it.

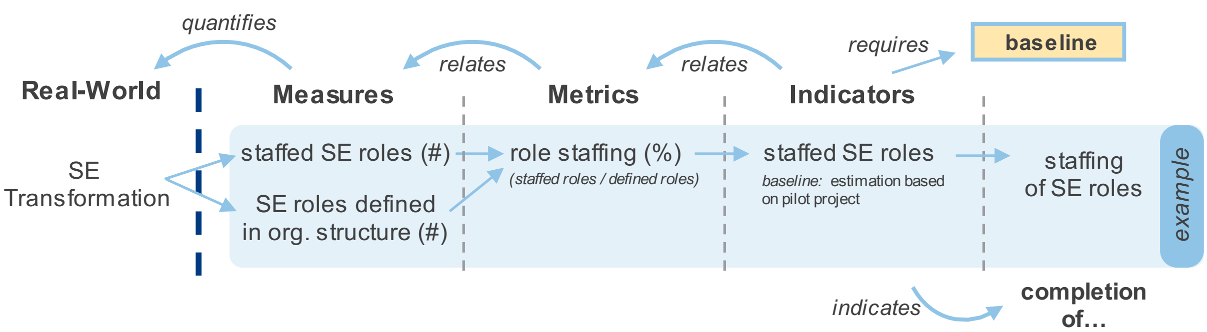

Figure 3. Example of relations between measures, metrics and indicators in context of SE Transformation according to the ISO/IEC/IEEE 24765 and Texel (Texel, 2013)

To achieve reliable indicators, a practice-proven robust baseline is required. As authors point out (Heihoff-Schwede et al., 2019; Landtsheer et al., 2006), piloting in SE allows to reduce the risk of transformation. When piloting SE in the organization, first a tailoring on the border conditions of the transformation target is performed. Further, processes, methods, tools and structures (PMTS) are developed according to this frame. During the tailoring of the SE approach for its application in the organization, a conceptional baseline is derived as a foundation for the practical application in the pilot project. On this basis, a first pilot project is carried out to prove the applicability and added value of Systems Engineering. During the pilot project, these foundations are validated and possibly adjusted in aspects for better applicability. The conceptional baseline with the practical adjustments from the pilot is consolidated as a baseline for further piloting or roll-out in the organization and its maturity assessment (see Figure 4).

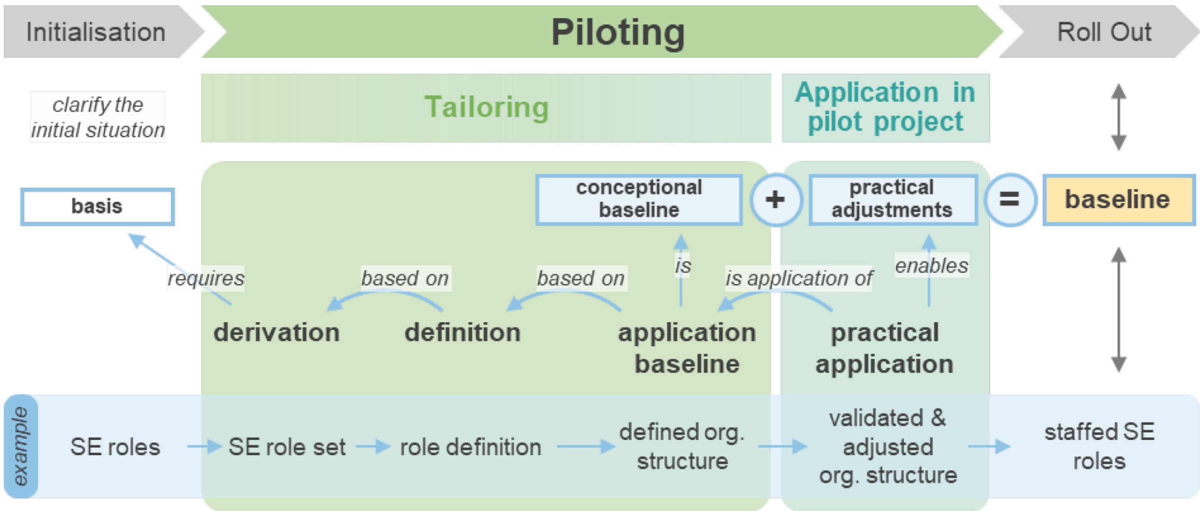

Figure 4. Piloting enables a reliable baseline for maturity assessment in SE roll-out

As visualized in the information model above (Figure 4), the first step of tailoring is to derive a set of SE roles from a fundamental SE approach (such as INCOSE) and the analyzed initial framework conditions. Based on this derivation, the required SE roles are defined for their application in the organization. The organizational structure is then defined based on these role definitions and the needs of the organization, taking into account, for example, the system breakdown structure. In the practical application of these fundamentals in a first pilot project, the defined organizational structure is considered as a baseline for the indicator of the 'staffed SE roles' an estimation based on the defined organizational structure is set (see Figure 5).

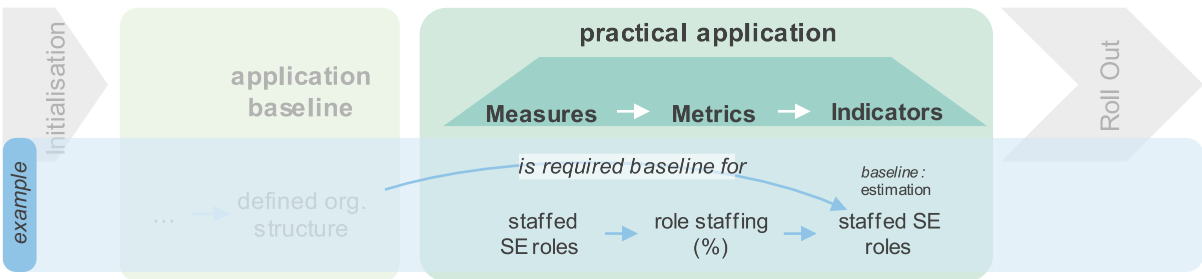

Figure 5. Maturity assessment in a pilot environment based on the conceptional baseline

Based on criteria of SE Transformation measurement derived from literature in previous research work (anonymous author, 2024), measures, metrics and indicators are consolidated. The categorization is done in six dimensions (see Figure 6) which are subdivided in categories containing 69 criteria in total.
While established maturity models, which set a specific focus on the content-related application of Systems Engineering, consider mainly criteria related to the dimensions 'portfolio' and 'PMTS', this approach offers a holistic assessment of the transformation.
In the following figure 7, an exemplary part of the derived measures, metrics and indicators in relation to a defined baseline are shown from the dimension 'organization'. 76 measures, metrics and indicators

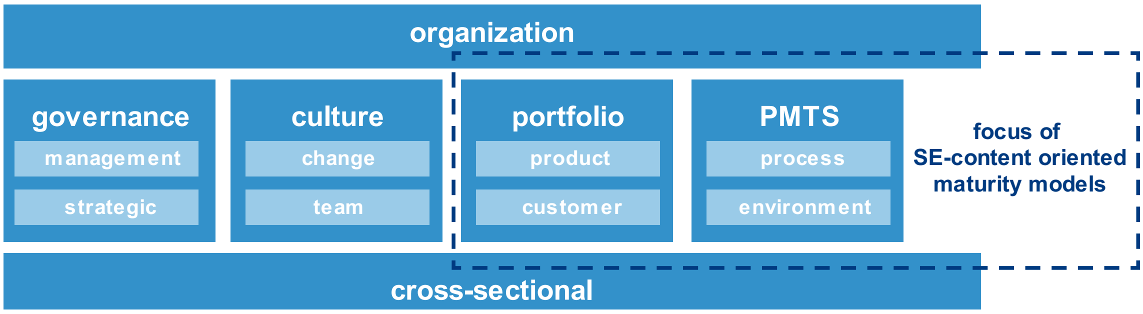

Figure 6. Dimensions of this maturity model

(each) are derived in total. In contrast to existing maturity models fundamentally, no assessment in terms of a qualitative performance level is done, but quantitative numbers are measured in SE implementation. By doing so, achievement of the defined transformation target can be monitored independent of a qualitative level, such as fragmented, established or optimized. The measures defined in this model can be derived from project documentation or collected in interviews with experts.
The aim of this model is to achieve an objective, fact-based data basis for transformation steering including the definition of measures for adjustment of the transformation program. Nevertheless, essential criteria exist, which can't be measured directly or represented by indicators indirectly on a quantitative way. Therefore, the proposed model by (Wilke et al., 2022) containing 5 levels (0 - not aware present, 1 - individual / ad hoc, 2 - fragmented, 3 - established, 4 - optimized) is used to translate qualitative data into quantitative measures. To identify the level of qualitative data ether expert interviews can be held or assessment can be done based on observations of meetings and workshops, for instance.

organization				
criteria	**measure**	**metric**	**indicator**	**baseline**
collaboration / definition of external interfaces	external interfaces (#)	degree of defined external interfaces (%)	defined external interfaces	estimation of defined interfaces (pilot)
collaboration / operatio-nalization of interfaces	operationalized external interfaces (#)	degree of operationa-lized interfaces	operationalized external interfaces	number of external interfaces (current)
structure / establishing of communication formats	established communi-cation formats (#)	degree of established communication flow (%)	established communi-cation formats	estimation of estab-lished formats at this time of project (pilot)
Structure / establishing of working groups	established technical working groups (#)	established working groups (%)	established technical working groups	
structure / staffing of SE roles	staffed SE roles (#)	role staffing (%) (staffed roles / defined roles)	staffed SE roles	estimation of staffed roles at this time (pilot)
…	…	…	…	…

key: identified by Graessler & Grewe 2024; baseline resulting from **current** project; baseline resulting from **pilot** project

Figure 7. Excerpt from the measures, metrics and indicators from the dimension 'organization'

5. Metric-based SE Transformation progress assessment and forecast

The derived measures, metrics and indicators lay the foundation for the evaluation of the transformation maturity. As shown in figure 8, different curves of the defined indicators can be estimated. As a baseline, the specific curves of the conducted pilot project can be set. Based on these two different views of monitoring can be taken: the transformation target achievement and an estimated transformation forecast. The transformation target achievement consists of the monitoring in terms of its 100% achievement in comparison to the baseline, a prior conducted pilot project or project in different units for instance. Therefore, an achievement higher than the baseline can be interpreted as good performance, while

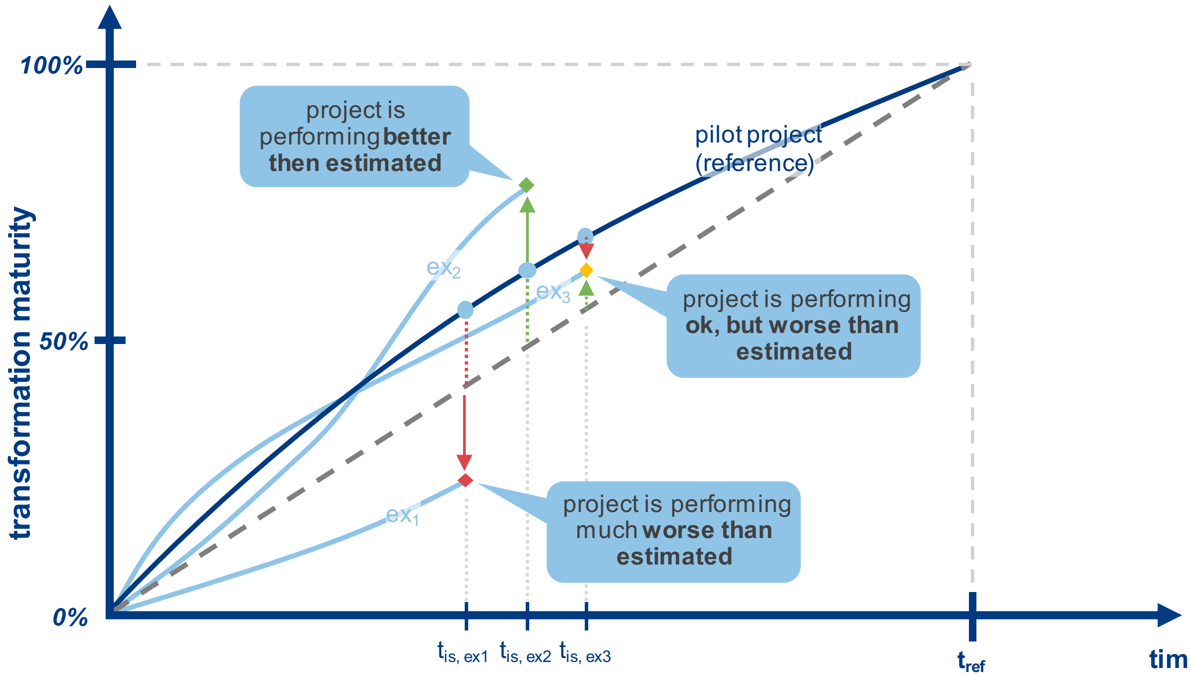

Figure 8. Target achievement and progress view on SE Transformation based on the analysis of the defined indicators

achievement lower than the baseline project means worse performance. More than that the current situation needs to be interpreted by experts considering external influences and strategic decisions which may give reason to the current situation.

In order to make an estimated forecast of further progress, it is possible to use either the current level or the gradient of the curve. As illustrated in figure 9, the distinct as-is status in conjunction with the prevailing gradient suggests the necessity for disparate action measures. For instance, performance level exceeding the reference point but exhibiting a negative gradient indicates the necessity for heightened awareness. Based on this forecast, further strategic planning of transformation steering can be undertaken.

The assessment proposed requires continuous curves of performance. Therefore, it is essential to conduct regular evaluations of transformation maturity and its documentation. Based on this concept of progress assessment presented on a high-level transformation view in the previous figures, increasing the granularity can be achieved by a more detailed view on the current status of the different dimensions, as proposed in figure 6.

The aforementioned, primarily visual, interpretation of transformation performance provides a straightforward method for estimating the current and projected status of transformation. Further,

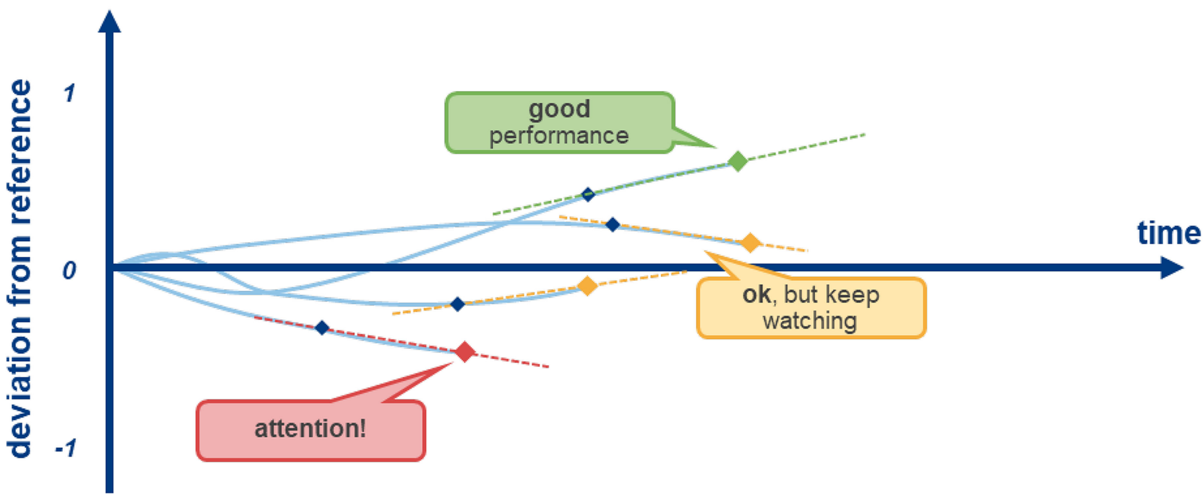

Figure 9. Forecast estimation based on current gradient

data-driven approaches can be employed to forecast future developments with greater precision and identify critical patterns. Therefore, next to fundamental approaches of time series analysis, such as autoregressive integrated moving average (ARIMA) and Bayes' timeseries model, machine learning approaches, such as regression models or long short-term memory networks (LSTM) as well as recurrent and convolutional neural networks (RNN and CNN) can be used.

6. Discussion and reflection

The shift of paradigm in the engineering of complex technical products and the need for adapted and new working models is omnipresent and visible in key figures such as engineering costs, delivery delays and quality indicators. The transformation process represents a major challenge in terms of costs and capacity and must be managed transparently. Previously accompanied transformation processes of the authors at global players in the automotive and commercial vehicle industry show the following need for actions: lack of objectivity in the measurement of progress; little to no consideration of cultural factors like employee acceptance, instead focusing entirely on process measurement; insufficient consideration of interfaces to non-transformed areas/companies, lack of communication of necessity and progress. However, all these aspects are success factors in the transformation of companies and have been integrated, beside previous scientific approaches, in presented model.

Selected elements of the model have been applied in practice of automotive sector and reflected in regard of the following decribed potential and limitations. Overcoming the limitations represents an initial starting point for transferring the approach from automotive sector to other industries, which will be investigated in greater depth in further research.

The model considers not only technical and process aspects in a comprehensive view of SE Transformation but also employee acceptance and commitment. By engaging employees as a pivotal element in the transformation, the needs and expectations of employees are incorporated, enhancing the credibility of the transformation and establishing a foundation for long-term acceptance. By making the transformation objective and transparent, the apprehensions and uncertainties of the workforce are mitigated, potentially increasing the likelihood of success of the transformation. The model provides a basis that can and must be flexibly adapted to the individual needs and framework conditions of the respective company. This 'customizing' ensures that specific company goals and resources are taken into account. A notable benefit of the model is its ability to objectively quantify and qualify the transformation process. This data-based approach guarantees that decisions are made on a fact-based foundation, thereby providing a robust foundation for strategic planning. Substantially collected data can be utilized for both internal communication and conceptual decision-making. The current status quo is precisely mapped with the help of data, and potential future developments can also be estimated by analyzing and evaluating this data. This enables transformation leaders to identify potential risks and opportunities of the transformation at an early stage and act accordingly.

While the maturity model offers a number of advantages, it is important to consider the potential limitations and challenges that may arise during implementation.

A significant challenge in the implementation of the model is the extensive range of evaluation criteria. While this allows for a thorough and comprehensive analysis, it also hinders the model's manageability and increases the required application effort. Consequently, the assessment may be conducted intermittently, for instance due to a lack of resources, which can result in an incomplete and highly fragmented data foundation. Furthermore, data quality and completeness are constrained by the accessibility of data. For instance, data protection regulations may prohibit the collection or utilization of personal data. These challenges in terms of data quality highlight the necessity for specialized data preparation for a meaningful application of the model.

In consequence, the use cases of the model developed must be narrowed down. It is not so much the sector itself, but rather the size of the company that is decisive for the possible application of this model. The key factors here are the capacities tied up, both in terms of personnel and budget and the duration of the transformation. The scope of the transformation also plays a role; as the cost/benefit of the presented model, even being customisable, in short-term small transformation in the collaboration models is difficult to communicate.

Last but not least, the evaluation of the data, as presented, can be largely automated; however, the result requires an individual interpretation and inclusion of surrounding influences that cannot be mapped by automation. Consequently, the model can be used to evaluate project developments on a fact-based basis. However, project developments must be specifically interpreted and evaluated by project experts to

provide a sound basis for decision-making. Furthermore, the forecast of future developments requires well-founded, data-based models to enable a realistic forecast.
Based on the insights and the reflection from the application of the proposed model in industrial practice, guidelines for its further implementation have been defined. First, the transformation steering model must be tailored according to the organizational framework (size, competencies, budget, . . .) as well as to the needs and goal of the transformation under consideration. In order to obtain a differentiated picture of progress, it is necessary to initiate and plan the progress evaluation before the start of a pilot project. Following key activities of applying the presented model are derived:

- Assign indicators to concrete, available measures in the organisation
- Define the procedure for data collection
- Define survey and evaluation intervals
- Define references for progress evaluation (plan values or reference values of a pilot project)
- Analyse transformation progress and define action plans

The use of the model requires a clear organisational structure (roles, responsibilities, management involvement, . . .) with a continuous and customized communication across all levels. Therefore, the identified indicators for the measuring can be used. An efficient transformation requires sustainable fact-based decisions to be made as early as possible, taking into account the objectives of the transformation and the cost/benefit ratio.

7. Conclusion

As part of this research, weaknesses in existing maturity models for SE Transformation were identified. Based on this, a maturity model is presented that builds on quantitative metrics and enables an overarching view on the transformation. Criteria for evaluating SE Transformation derived from the literature and structured in five dimensions lay the foundation for the derivation of measures and its reference to metrics and indicators. A core feature here is the baseline of the indicators, which lies in the implementation of the pilot project and thus forms a practically tested and realistically achievable reference. The relationship between measures, metrics and indicators is supported by an information model, which is used to illustrate the relevance of piloting in the SE Transformation for a reliable maturity assessment of the transformation and builds on the existing standard of the ISO/IEC/IEEE 24765. Based on these measures, metrics and indicators, a model for SE Transformation target achievement as well as progress forecast is presented. To achieve a clear and unmistakable transformation progress view, data must be collected in appropriate numbers and regular cycles, which typically leads to high amounts of data with lacking values in large companies. Challenges of extreme data, in terms of processing large numbers of data and lacking data, for instance, need to be solved by approaches of timeseries analysis, data science or artificial intelligence.
Due to its data-centricity, the model presented in this research enables a more comprehensive, fact-based decision-making basis for the design and steering of SE Transformation programs. More than this, this research offers an employee centric approach which considers culture as a central topic of Systems Engineering Transformation. Discrepancies of transformation can be identified at an early stage and appropriate action can be taken to ensure the transformations success. Elements of this approach had been applied in automotive industry. In the next step of this research, the comprehensive model will be applied and evaluated in transformation projects of different sectors. Further, research is required in mathematical models for the description of the transformation process and its forecast. Therefore, approaches of data science and artificial intelligence can be explored.

Author Contributions

conceptualization, methodology, investigation, writing, and visualization, B.G.; discussion and reflection, and review L.F.; review and editing, and supervision I.G. All authors have read and agreed to the published version of the manuscript.

References

Arnold, E., & McKinney, D. (2022). Enabling Systems Engineering in an Unsupportive Environment. *INCOSE International Symposium*, 32(1), 105–123.

Bate, R., Kuhn, D., Wells, C., Armitage, J., & Clark, G. (1995). A Systems Engineering Capability Maturity Model, Version 1.1. *Defense Technical Information Center*.
Boes, A. (2024). Cariad-Scheitern zeigt deutsche Schwächen. *Frankfurter Allgemeine Zeitung*.
Bretz, L. (2021). Rahmenwerk zur Planung und Einführung von Systems Engineering und Model-Based Systems Engineering. *Dissertation*. Heinz Nixdorf Institut, Universität Paderborn.
Cornu, C., Chapurlat, V., Quiot, J.-M., & Irigoin, F. (03 2012). A maturity model for the deployment of Systems Engineering processes. In *2012 IEEE International Systems Conference SysCon* 2012 (pp. 1–6). IEEE.
Cusick, K. (1997). The systems engineering capability maturity model: where to start? Advance online publication.
Davey, C. (2020). INCOSE Automative Vision 2025.
David D. Walden, Garry J. Roedler, Kevin J. Forsberg, & R. Douglas Hamelin and Thomas M. Shortell (2015). INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities.
Department of Defense. (2022). Systems Engineering Guidebook.
Graessler, I., Thiele, H., Grewe, B, & Hieb, M. (2022). Responsibility Assignment in Systems Engineering. *Proceedings of the Design Society*, 2, 1875–1884. https://doi.org/10.1017/pds.2022.190
Graessler, I., & Grewe, B. (2024). Importance of cultural change in Systems Engineering Transformation: A model for cultural assessment. In *AHFE International, Human Systems Engineering and Design (IHSED2024) Future Trends and Applications*. AHFE International.
Graessler, I, Oleff, C, & Hentze, J. (2019). Role Model for Systems Engineering Application. *Proceedings of the Design Society: International Conference on Engineering Design*, 1(1), 1265–1274.
Graessler, I, Wiechel, D., & Pottebaum, J. (2021). Role model of model-based systems engineering application. *IOP Conference Series: Materials Science and Engineering*, 1097(1), 12003.
Gräßler, I. (2015). Umsetzungsorientierte Synthese mechatronischer Referenzmodelle. In VDI (Ed.), *Fachtagung Mechatronik 2015*. Dortmund, pp. (pp. 167–172).
Gräßler, I., & Oleff, C. (2022). Systems Engineering: verstehen und industriell umsetzen. Springer Berlin Heidelberg.
Hartwich, E. (2014). Grundlagen Change Management: Organisationen strategisch ausrichten und zur Exzellenz führen (1. Auflage). *Schriftenreihe der Führungsakademie Baden-Württemberg*. Richard Boorberg Verlag GmbH & Co KG.
Heihoff-Schwede, J., Bretz, L., Kaiser, L., & Dumitrescu, R. (2019). An Explanatory Model as Basis for the Introduction of Systems Engineering and capable IT-Infrastructures in Industry. In *2019 International Symposium on Systems Engineering (ISSE)* (pp. 1–8). IEEE.
INCOSE. (2023). Incose Systems Engineering Handbook (5th ed.). John Wiley & Sons Incorporated.
ISO/IEC/IEEE 24765:2010. Systems and software engineering - Vocabulary (International Standard 24765).
Kasser, J. E., & Frank, M. (2010). A Maturity Model for the Competency of Systems Engineers.
Landtsheer, B. de, Aartman, L., Jamar, J., Liefde, J. de, Malotaux, N., Reinhoudt, H., & Schreinemakers, P. (2006). Implementing Systems Engineering: A Step-By-Step Guide. In *Fifth European Systems Engineering Conference*.
Moedritscher, G., & Wall, F. (2022). Controlling and Change Management. In M. Karmasin, S. Diehl, & I. Koinig (Eds.), *Media and Change Management* (pp. 73–85). Springer International Publishing.
NASA. (2007). NASA Systems Engineering Handbook.
Page, M. J., Moher, D., Bossuyt, P. M. *et al.* (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews, BMJ 2021;372:n160. doi: https://doi.org/10.1136/bmj.n160
Schulze, S.-O., Tschirner, C., Kaffenberger, R., & Ackva, S. (Eds.) (2017). Tag des Systems Engineering: Herzogenaurach, 25.-27. Oktober 2016. Hanser eLibrary. Hanser.
Schulze, S.-O., & Steffen, D. (2018). Systems Engineering Quick Check. *INCOSE International Symposium*, 28(1), 688–699.
Sheard, S. A. (1996). Twelve Systems Engingeering Roles. *INCOSE International Symposium*, 6(1), 478–485.
Sheard, S. A., & Lake, J. G. (1998). 2.5.1 Systems Engineering Standards and Models Compared. *INCOSE International Symposium*, 8(1), 591–598. https://doi.org/10.1002/j.2334-5837.1998.tb00086.x
Steffen, D., Enge, E., Schulze, S.-O., & Czaja, A. (2017). Pragmatisches Reifegradmodell zur Einführung von Systems Engineering. In S.-O. Schulze, C. Tschirner, R. Kaffenberger, & S. Ackva (Eds.), *Hanser eLibrary, Tag des Systems Engineering: Herzogenaurach*, 25.-27. Oktober 2016 (pp. 269–278). Hanser.
Texel, P. P. (2013). Measure, metric, and indicator: An Object-Oriented approach for consistent terminology. In *2013 proceedings of IEEE SoutheastCon*: Jacksonville, Florida, USA, 4 - 7 April 2013. IEEE.
White, B. E. (2016). On a maturity model for complexity, complex systems, and complex systems engineering. *International Journal of Design & Nature and Ecodynamics*, 11(4), 532–542.
Widmann, E. R. (1998). 2.5.2 Key Features of the "Merged" EIA/IS 731–1 Systems Engineering Capability Model. *INCOSE International Symposium*, 8(1), 599–606.
Wilke, D., Pfeifer, S. A., Heitmann, R., Anacker, H., Dumitrescu, R., & Franke, V. (2022). Implementation of Systems Engineering: A maturity-based approach. In *2022 IEEE International Symposium on Systems Engineering (ISSE)* (pp. 1–7). IEEE.