INTERNATIONAL DESIGN CONFERENCE – DESIGN 2022
https://doi.org/10.1017/pds.2022.190

Responsibility Assignment in Systems Engineering

I. Gräßler, H. Thiele ✉, B. Grewe and M. Hieb
Paderborn University, Germany
✉ henrik.thiele@hni.upb.de

Abstract

Increasing system complexity can be controlled by using systems engineering processes. INCOSE defines processes with inputs and outputs (artifacts) for this purpose. Specific SE roles are used to organize the tasks of the processes within the company. In this work, the responsibilities for artifacts are evaluated by means of the RACI scheme and examined by a cluster analysis and discussed for a SE transformation project with a German automotive OEM. As a result of the study, the optimal composition for systems engineering teams is identified and the systems engineering roles are prioritized.

Keywords: systems engineering (SE), project management, model-based systems engineering (MBSE)

1. Introduction

Increasing system complexity leads to multiple challenges in the development of highly complex systems (Haberfellner 2012). *To tackle these challenges, the product development of an organization can be structured by applying the principles and processes of Systems Engineering. Based on the processes defined by the* ISO/IEC 15288 for the application of Systems Engineering, International Council on Systems Engineering (INCOSE) defines inputs, outputs, controls, enablers and activities for each Systems Engineering process (Walden et al. 2015). The challenges in the application of systems engineering in companies lie in particular in the transfer of theoretical approaches into specific tasks for specific roles with competencies and responsibilities. This is critical, among other things, as responsibilities are not clearly specified in literature and Systems Engineering handbooks. Initial approaches to simplify the transfer of practice are offered by competency models, such as those described by the U.S. Department of Defense (Whitcomb et al. 2017; White et al. 2016).

The approach in this paper is based on three steps to derive a responsibility assignment combining Systems Engineering and Project Management roles. First, Systems Engineering roles are identified and selected based on a broad literature research and then relevant Systems Engineering artefacts are selected from the INCOSE Handbook. In the last step the dependencies between Systems Engineering roles and artefacts are assessed with a RACI-scheme (Responsible, Accountable, Consulted, Informed) based on practical experience from industrial projects with a leading automotive company. For the analysis and evaluation of the approach, a cluster analysis has been performed to identify team compositions in Systems Engineering. The validation is based on the results and experiences of the application of the roles for a German automotive OEM.

2. State of the Art

Systems Engineering is a structured, cross-disciplinary approach to develop complex technical systems. The overall target is to achieve a cross-disciplinary optimum within a fixed time frame and a specified budget (Gräßler 2015), exploiting synergies of model-based, digital and systems engineering (Gräßler and Pottebaum 2022). Its scope includes the complete lifecycle from strategic planning to recycling of the system (Haberfellner 2012; Gräßler and Pottebaum 2021). Systems Engineering is based on System Thinking, which includes a clear delamination of the System of Interest with its elements and connections (Haberfellner 2012; Gräßler et al. 2018). A key task of Systems Engineering is the so called "Tailoring", which describes the configuration of Systems Engineering approaches (NASA 2007; United States Department of Defense 2001) to project specific conditions (Walden et al. 2015; Gräßler et al. 2018). This also applies to Systems Engineering roles, which also need to be tailored on the projects circumstances (Gräßler et al. 2018).

2.1. Role Models in Systems Engineering

To fulfil the objectives of Systems Engineering, the generic role of the Systems Engineer is divided into different specific roles, defined in a Systems Engineering role model. Moreover, there is a difference between roles and the people who act in form of a role. A systems engineer can have multiple roles at the same time. This happens especially for smaller projects and roles which have a contrary workload in the product creation process. Also, one role can be fulfilled by different people within the same project. (Gräßler et al. 2019)

In Systems Engineering research, different role models were published by various authors. The first role model for Systems Engineering was published by Sheard in 1996 (Sheard 1996). Sheard identifies twelve different roles, where each role represents and defines activities and tasks to be taken into account when performing Systems Engineering through the entire system life cycle (Walden et al. 2015): Requirements Owner, System Designer, System Analyst, Validation/Verification Engineer, Logistics/Ops Engineer, Glue Among Subsystems Customer Interface, Technical Manager, Information Manager, Process Engineer, Coordinator, Classified Ads SE. These twelve roles mark the starting point for adjustments and changes in Systems Engineering role models. The adjustments and changes to the existing models are performed and based on different aspects, as experience in industrial practice (Gräßler et al. 2019) or emerging trends in Systems Engineering (Selig and Baltes 2017). The differences in roles are based on different allocations of tasks and competencies (Selig and Baltes 2017).

As of 2021, for the field of Systems Engineering nearly 200 relevant publications on roles models can be identified. This is extended by a total of 1194 publications when broadened to the fields of Project Management and Organizational Management. A condensation of these publication, performed by Gräßler et el. leads to a total of 213 roles in Systems Engineering, which can be reduced by semantic analyses to 66 mutually exclusive roles (Gräler et al. 2021).

2.2. Responsibility Assignment in Industrial Practice

Unclear responsibilities for activities and missing life-cycle ownership lead to tumbling projects in industrial context. To avoid unclear project organization, methods are required to structure and assign the responsibilities of tasks in project organization. The RACI matrix is commonly used to visualize roles and responsibility of individuals who are involved in a process or organization (Costello 2012; Jacka and Keller 2009). RACI is an acronym and describes four kinds of responsibilities which are held by individuals in a process. The rule set of RACI, following (Costello 2012), is as follows:

- R - responsible: The responsible person (R) performs the work of the task.
- A - accountable: There should be just one accountable person (A) for each task. This person might not be the one who actually does the work, but answers the completion and success of the task. Especially for small teams, R and A can be held by the same person.
- C - consulted: The consulted persons (C) are requested to provide input based on their experience and competencies.
- I - informed: I-persons need to be informed about the current status but don’t have any action in the task.

Based on the RACI method, most commonly used in industrial practice (Costello 2012), there are different variants and further developments (RASI, RASCI, RASCI-VS, RACIO etc.) which extend the scope and the rule set of RACI to more detailed responsibilities such as **S**upport (S) (Tealeb et al. 2016).

3. Approach

The derivation of most role models is based on the description and allocation of tasks and processes (Gräßler et al. 2021). The focus on processes assures an overall Systems Engineering conformity in product development, since for each step, a responsible and accountable person is assigned. To introduce Systems Engineering into industrial practice, a result-based perspective needs to be taken, apart from a procedural perspective. In addition to the application of all processes, the focus on Systems Engineering artefacts, e.g. RVTM, assures each outcome and input of the Systems Engineering processes is accounted for. The result-based perspective therefore builds on the procedural perspective.
A result-based perspective on Systems Engineering can be achieved by deriving a generic responsibility assignment matrix for relevant Systems Engineering artefacts. To derive such a responsibility assignment matrix, the following approach is chosen (cf. Figure 1):

1. Identification of a representative Systems Engineering role model
2. Identification of relevant Systems Engineering artefacts
3. Derivation of a generic responsibility assignment matrix

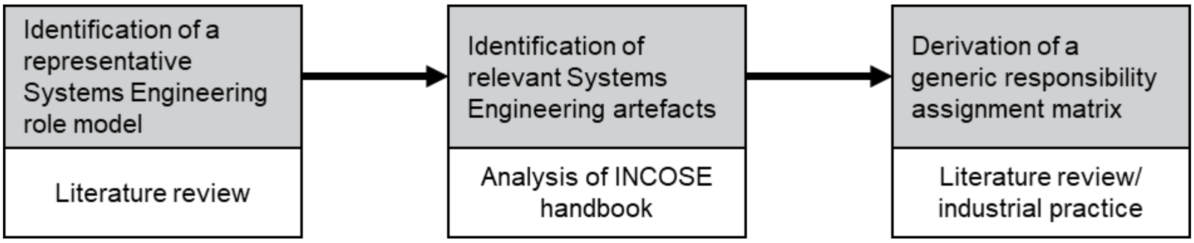

Figure 1. Approach in deriving a generic systems engineering responsibility assignment matrix

The second and third step were performed by the authors independently and then matched to minimize errors. The resulting responsibility assignment matrix is then analysed regarding clusters within the roles and artefacts and additionally reflected in the context of and Systems Engineering transformation process in leading German automotive manufacturer. As a result, team compositions for the Systems Engineering roles can be identified. To identify related work, a literature review in the databases Science Direct and Google Scholar have been performed, especially on the topic of IPO diagram analysis. The search has been narrowed down to results in the context of systems engineering, which did not yield any relevant results for an explicit responsibility assignment in Systems Engineering.

4. Identification of a Representative Systems Engineering Role Model and Relevant Systems Engineering Artefacts

In order to assess the relationship between roles and Systems Engineering artefacts, representative role models as well as Systems Engineering artefacts need to be analysed and selected.

4.1. Representative Systems Engineering Role Model

Since the first role model by Sheard in 1996, additional role models for Systems Engineering were published. Since 2021, more than a thousand publications on role models can be identified in the databases Web of Science and Google Scholar (c.f. section 2.1). To select a representative role model, the meta study of Gräßler et al is taken as a basis. In the meta study by Gräßler, 66 mutually exclusive were analysed regarding their fitness to (Model Based) Systems Engineering processes and through multilinear scaling the 66 roles were reduced to 15 roles, applicable for Systems Engineering.
In that meta-study, Gräßler et al. adapted the previously published role set (Gräßler et al. 2019) with regard to two roles, namely the Leader (in 2018) and Project Leader (in 2021). As in (Gräßler et al. 2019), a bottom-up approach is taken by matching Systems Engineering competencies with the role model in industrial practice, the updated role model is chosen as a representative Systems Engineering role model for this publication. The 15 roles and a short description are given below:

https://doi.org/10.1017/pds.2022.190 Published online by Cambridge University Press

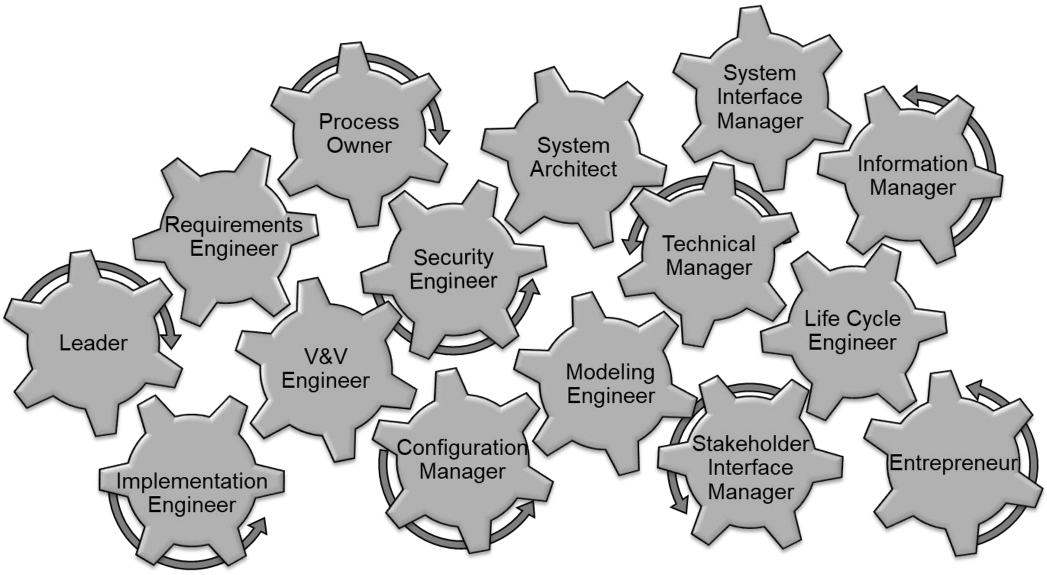

Figure 2. Role model for systems engineering application (based on (Gräßler et al. 2021))

1. **Modelling Engineer**: In charge of the representation of all relevant aspects, including system elements, behaviour and properties, its internal and external interfaces and the environment in an adequate model and the deduction important information from the ensemble of models.
2. **System Architect**: Responsible for the design of the system architecture, identification of different architecture alternatives and the selection of the most suitable alternative.
3. **System Interface Manager**: In charge of the overarching harmonization of the different system elements creating of an overall optimum.
4. **Technical Manager**: Entrusted with the technology-based decisions of the System of Interest; needs to understand, evaluate and select candidate technical solutions on different levels of detail and based on appropriate technical measures.
5. **Project Leader**: Focus on inspiring employees involved in the Systems Engineering project and delegating work according to their strength and weakness and ensures that decisions are forward-looking and the result of seeking a win-win solution.
6. **Stakeholder Interface Manager**: Ensurance of stakeholder satisfaction, including the elicitation, definition and understanding of their needs and transforming of needs into requirements afterwards and keeping the set of requirements consistent to the stakeholder needs.
7. **Requirements Engineer**: Ensurance about one or several requirements from all stages (stakeholder needs, stakeholder and system requirements) of a Systems Engineering project and ensurance, that all requirements are consistent with higher-level and lower-level requirements.
8. **Life Cycle Engineer**: Responsible of the implementation of a holistic life cycle perspective into all decisions on each level of the system, including very detailed developments of small parts and elements, especially the introduction and communication of relevant restrictions and boundary conditions from all system life cycles.
9. **Implementation Engineer**: Responsibility of coordinating and executing the realization of all system elements according to the architecture and design specifications.
10. **Validation and Verification Engineer**: Facilitation of the stakeholder satisfaction and responsibility for measuring system performance (Verification) and stakeholder needs fulfilment (Validation) by planning and implementing the verification and validation actions.
11. **Security Engineer**: Taking the security perspective on the entire technical system of interest.
12. **Process Owner**: Responsibility of defining, implementing, controlling, evaluating and modifying related processes within the organization.
13. **Configuration Manager**: Focus on making all kinds of outputs like artefacts, objects or documents outputs available for concerned parties and ensurance that system integrity is considered at all decision points, meaning that the approval of every output needs to consider the technical (product), business (business case) and budget (funding) aspects equally.

https://doi.org/10.1017/pds.2022.190 Published online by Cambridge University Press

14. **Information Manager**: Ensurance of making high quality of all kind of information available to concerned stakeholders.
15. **Entrepreneur**: Taking of a superordinate perspective and initiation of thinking about business aspects like costs, pricing and rates.

4.2. Relevant Systems Engineering artefacts

Within ISO/IEC 15288, 14 Technical Processes (TP), 8 Technical Management Processes (TMP), 2 Agreement Processes (AP) and 6 Organizational Project-Enabling Processes (OPEP) for the application of Systems Engineering are defined. The INCOSE handbook elaborates on these processes and defines inputs, outputs, controls, enablers and activities for each process. Consequently, an input-process-output diagram (IPO diagram) is defined for each process. Each IPO diagram visualizes the transformation of a certain number of inputs through distinct activities into a certain number of outputs. The diagrams illustrate one way to apply each Systems Engineering process but not necessarily the only way. The results of the processes are the outputs in each IPO diagram and can be final results or inputs for other processes. For a result-based perspective on the responsibility assignment in Systems Engineering, the set of all inputs and outputs should be considered and be accounted for, as the set of all Systems Engineering artefacts. The approach used to identify the relevant Systems Engineering artefacts based on the IPO diagrams is illustrated in Figure 3:

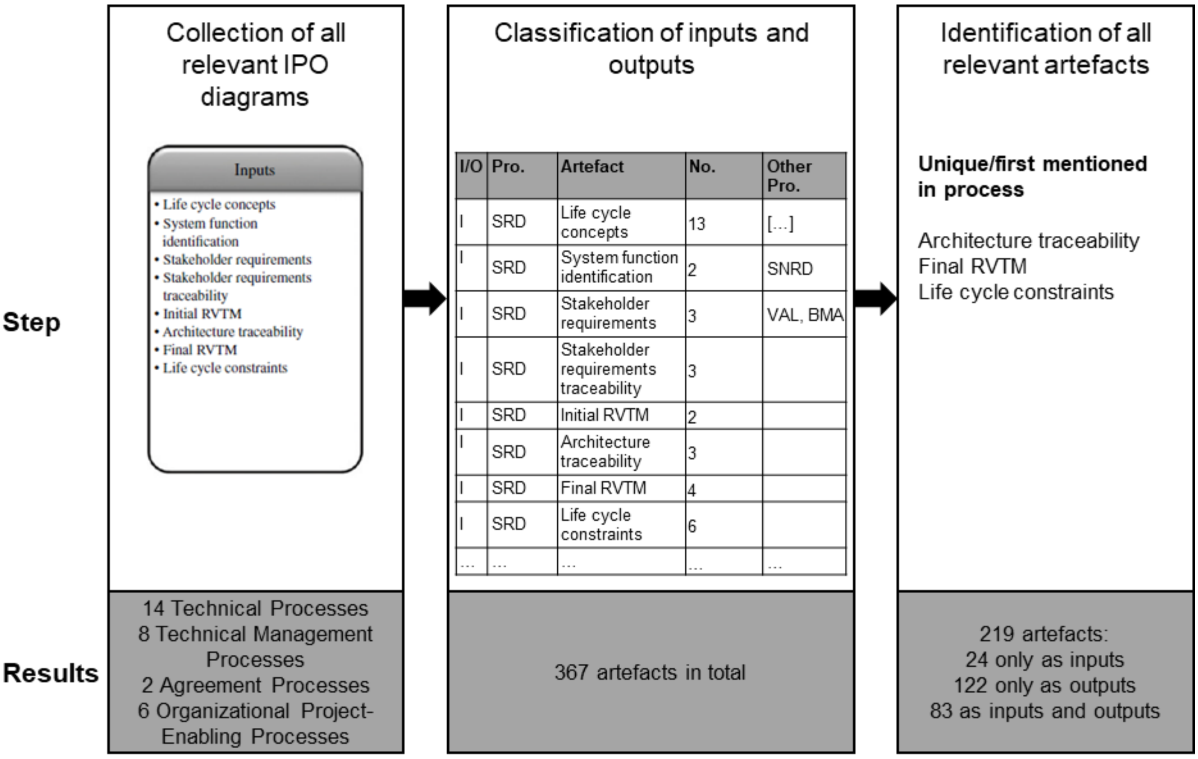

Figure 3. Approach to identifying relevant systems engineering artefacts

Within the IPO diagrams of the Systems Engineering artefacts, 60 sets of in- or outputs are given. Overall, 367 artefacts can be identified within the sets of inputs and outputs. Firstly, the 367 artefacts are classified by input/output, process, number of appearances and other processes they appear in. As some artefacts function as inputs and outputs for different processes, the duplicates are labelled and reduced to only on entrance in the artefact list. Therefore, the number of artefacts can be reduced to 219 unique artefacts. Out of the 219 artefacts, 24 function as inputs, 122 as outputs and 83 as both inputs and outputs. The most connected artefact is the "Life cycle concept", as it is in- or output for 13 different processes. The 219 unique artefacts are taken as an input for the responsibility assignment. The overall number of inputs/outputs and number of unique inputs per Systems Engineering process is displayed in Table 1:

https://doi.org/10.1017/pds.2022.190 Published online by Cambridge University Press

Table 1. Number of input and outputs per systems engineering process

Cath.	Process	Unique input	All input	Unique output	All output
TP	Business or Mission Analysis Process (BMA)	1	6	2	11
TP	Stakeholder Needs and Requirements Definition Process (SNRD)	1	15	4	10
TP	System Requirements Definition Process (SRD)	0	8	4	10
TP	Architecture Definition Process (AD)	0	9	2	9
TP	Design Definition Process (DD)	0	13	4	9
TP	System Analysis Process (SA)	1	3	3	3
TP	Implementation Process (IMP)	0	8	5	9
TP	Integration Process (IN)	0	7	5	8
TP	Verification Process (VER)	0	7	5	8
TP	Transition Process (TP)	0	5	5	8
TP	Validation Process (VAL)	0	6	5	8
TP	Operation Process (OPER)	0	6	4	5
TP	Maintenance Process (MAINT)	0	6	5	6
TP	Disposal Process (DISP)	0	4	6	7
TMP	Project Planning Process (PP)	2	13	2	9
TMP	Project Assessment and Control Process (PAC)	2	11	5	8
TMP	Decision Management Process (DM)	1	1	3	3
TMP	Risk Management Process (RM)	1	1	3	3
TMP	Configuration Management Process (CM)	1	2	3	4
TMP	Information Management Process (INFOM)	1	2	3	4
TMP	Measurement Process (MEAS)	2	2	3	4
TMP	Quality Assurance Process (QA)	0	4	1	4
AP	Acquisition Process (ACQ)	3	5	5	7
AP	Supply Process (SUP)	1	5	4	6
OPEP	Life Cycle Model Management Process (LCMM)	1	4	6	7
OPEP	Infrastructure Management Process (INFRAM)	0	3	5	5
OPEP	Portfolio Management Process (PM)	1	4	3	7
OPEP	Human Resource Management Process (HRM)	0	3	3	4
OPEP	Quality Management Process (QM)	1	5	1	6
OPEP	Knowledge Management Process (KM)	1	4	3	3

4.3. Derivation of a generic responsibility assignment matrix

In the third step of this approach, the responsibility assignment is performed, building on the results of the previous steps. As a responsibility assignment scheme, the RACI is applied, as it is best established in industrial practice (cf. section 2.2) (Costello 2012). For each artefact, the participation of the identified roles is evaluated. Each role is either responsible, accountable, consulted, informed, or none of the previous for the creation and update of each artefact. A role can be responsible and accountable at the same time for one artefact, but no other combination of assignment is allowed.
An excerpt of the resulting responsibility assignment matrix is given below in Table 2. An exemplary artefact is shown for each process. The complete responsibility assignment matrix (RAM) is given in https://engrxiv.org/5ujm8/. The assessment of the RAM is based on the roles and artefact descriptions as well as on experience and discussions in an industrial project.

https://doi.org/10.1017/pds.2022.190 Published online by Cambridge University Press

Table 2. Responsibility assignment matrix for Systems Engineering artefacts

Process	Artefact	Mod. Eng.	Sys. Arch.	Sys. Int. Mgr.	Tech. Mgr	Proj. Leader	Stake. Int. Mgr.	Req. Eng.	Life Cycle Eng.	Imp. Eng.	V& V Eng.	Sec. Eng.	Process Owner	Config. Mgr.	Infom. Mgr.	Entrepreneur
ACQ	Acquisition need	R	C	C		A				C		I		C	C	I
AD	Life cycle constraints								RA					C		I
AQ	Quality management corrective actions		C		A	C				R				C	I	
BMA	Business or mission analysis strategy					RA										C
CM	Project change requests				C	RA	C	C	C				C	C		
DD	System design description	C	A	C	I	I	C	C		R				C	C	
DISP	Disposed system								RA							
DM	Decision report				C	RA										I
HRM	Project portfolio					RA										C
IMP	Implementation strategy	C	A	C	C	I		C		R	I	C		C		
IN	Integration strategy				C	I				RA						
INFOM	Information repository														RA	
INFRAM	Project infrastructure	I	I	I	R	A	I	I	I	I	I	I	C	I	I	I
KM	Organization strategic plan					C							C			RA
LCMM	Life cycle models	C	C	C	C				RA	C				C		C
MAINT	Maintenance procedure				A			C	R					C		
MEAS	Measurement data			C						RA				C	C	
OPER	Operation enabling system requirements		C		C			C		RA				C		
PAC	Configuration baselines		C		C					C		C		RA		
PM	Portfolio management plan		C		C	A	C		C					C	I	R
PP	SEMP		C	C	R	I				C	C		A	C	C	
QA	Customer satisfaction inputs		C	C			RA	C								
SA	System analysis report	C	C		C			C		C	C	C	A		R	
SNRD	Stakeholder needs						RA									
SRD	System requirements definition record							RA								
SUP	Supply agreement				A	R		C								
TP	Verification report										RA				C	
VAL	Validation criteria		C	I				R			A					
VER	Final RVTM		C	C	C		C	A			R			C	C	

5. Evaluation

The evaluation of the resulting responsibility matrix is performed twofold. Firstly, a cluster-analysis is performed to identify similarities within the roles and to draw conclusions for team. Secondly, the results are reflected within an ongoing Systems Engineering transformation process.

5.1. Cluster Analysis for Systems Engineering Roles

Based on Table 2, which illustrates the responsibility assignment for the Systems Engineering artefacts, a cluster analysis is used to identify overlapping characteristics of each role. Each type of responsibility was assigned a numerical value, with decreasing importance from R over A and C to I. By calculating the difference between each column, the distance between each role can be calculated. Based on the

https://doi.org/10.1017/pds.2022.190 Published online by Cambridge University Press

resulting distance matrix, a classical multidimensional scaling to reduce the dimensions of the distance matrix has been applied.

To identify the Systems Engineering role clusters (cf. left in Figure 4), a dendrogram analysis and the hierarchical MATLAB-Cluster algorithm was performed. Based on the dendrogram (right hand side in Figure 4), the optimal number of clusters can be identified as four distinct clusters. The position of the roles in the 2-dimensional space is denoted by dimensionless indicators.

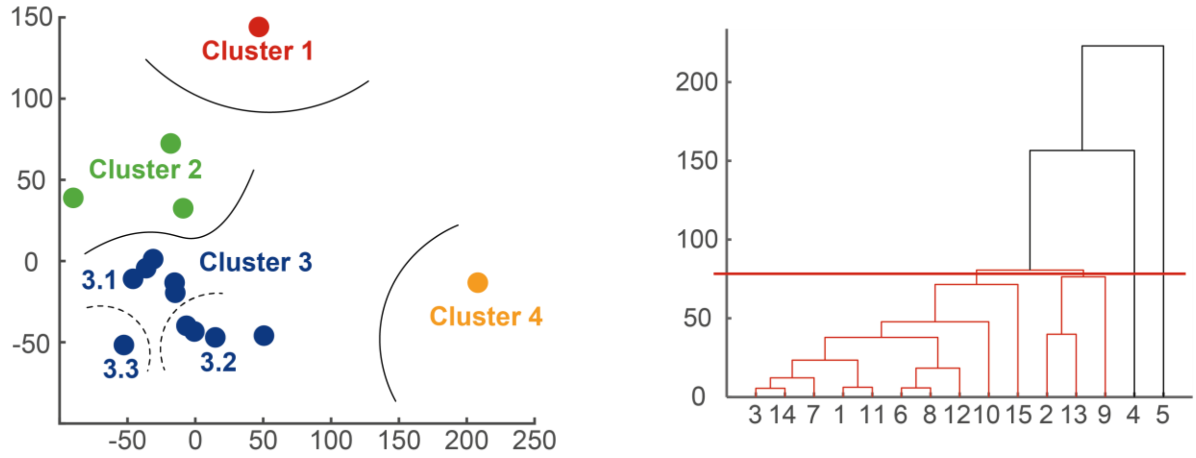

Figure 4. Cluster diagram (left) and dendrogram (right)

The results of the cluster analysis is given in Table 3. The results of the cluster analysis illustrate the closeness of certain roles, based on the responsibility assignment and all roles of the same cluster are of the same colour in Figure 4. The first and forth cluster only contain one role each - the Technical Manager and the Project Leader. The second cluster contains three roles, the System Architect, the Implementation Engineer and the Configuration Manager and lastly the third cluster contains all remaining roles.

Based on the roles in each cluster, different conclusions can be drawn. The Technical Manager is the only role in Cluster 1 and the Project Leader the only role in Cluster 4. Both clusters are far apart which is consistent with diverse competencies and tasks of the two roles. While the role of the Project Leader represents the organisational perspective, the Technical Manager represents the technical system view. Moreover, looking at the database (see table 3 and extended responsibility assignment matrix in https://engrxiv.org/5ujm8/), the Technical Manager and the Project Leader share different perspectives with regards to project artefacts. While the Technical Manager directs an artefact (represented by "RA"), the Project Leader usually stands on the informed side (represented by "I") and vice versa.

The remaining roles are divided into two clusters. Cluster 2 contains all roles which are consulted and entrusted with the architecture of the system itself, the "architecture teams" so to say. While the Systems Architect is entrusted with the general architecture of the systems, the Implementation Engineer covers the realization of the system elements, and the Configuration Manager tracks the overall system integrity and communicates the status and changes of the design to all relevant stakeholders. For a set of requirements and models, the architecture team is able to realize the system design and communicate it.

Cluster 3 contains all remaining roles and represents the specialist roles. A separation of the third cluster can be performed in two different ways. The first way is to introduce further variables and artefacts or change the RACI scheme. This approach would change the overall result and would not guarantee a more differentiated result. Therefore, a second approach was chosen, and the third cluster was clustered a second time, resulting in the three subclusters 3.1, 3.2 and 3.3. Similarly to the main clusters, the roles in the subclusters can be associated with different teams. The roles in subcluster 3.1 are associated with the artefacts of the technical processes and those artefacts closer to the system design. The roles in subcluster 3.2 on the other hand are closer to the management and organizational processes. The last cluster is the only cluster containing just one role with the Validation & Verification Engineer.

https://doi.org/10.1017/pds.2022.190 Published online by Cambridge University Press

Table 3. Clusters and their inherited roles

Cluster no.		Assigned roles
1		Technical Manager
2		System Architect, Implementation Engineer, Configuration Manager
3	3.1	Requirements Engineer, Information Manager, Security Engineer, Modelling Engineer, System Interface Manager,
	3.2	Stakeholder Interface Manager, Process Owner, Life Cycle Engineer, Entrepreneur
	3.3	Validation & Verification Engineer
4		Project Leader

Overall, the resulting clusters are therefore consistent with the assumptions for the description of the roles and artefacts. Based on the results of the cluster analysis, different team structures can be identified. On a high-level perspective, the Systems Engineering team should be divided into the technical management (1), architecture team (2), project management team (4) and a specialist team (3). The specialist team can furthermore be divided into the technical process team (3.1), an organizational team (3.2) and lastly a V&V team (3.3), thus resulting into four to seven different teams.

The composition of the teams is derived solely by focussing Systems Engineering artefacts. Different general conditions in an organization as well as a stronger focus on processes might result in another team composition. However, the results indicate which roles should be grouped into the same team, as they are in charge of similar artefacts. Since it is obvious from the role model, that a Project Leader is needed, the team assignment shows, that a Project Management team should contain only the Project Leader and not the Entrepreneur, who is assigned to a different team.

On a practical level, small Systems Engineering teams are to be staffed with at least four people, correlating with the four main clusters. In large scale Systems Engineering projects, the division of team 3 into 3 new teams is possible and should be enforced. A varying team size can be observed in large Systems Engineering projects with different system levels. While on the level of the System of Systems or the system level 1 a role can and will be fulfilled by more than one person, a Systems Engineering team on the level of system elements might only consist of a Technical Manager, System Architect, Project Leader and Specialist.

5.2. Application in Industrial Practice

The resulting responsibility assignment matrix and cluster analysis was subsequently reflected in comparison with the results of a Systems Engineering transformation process in a leading German automotive company. The company is currently carrying out a complete changeover of the product development process, which will be carried out in accordance with Systems Engineering in the future. Therefore, the required Processes, Methods, Tools and Operations (PMTOs) are developed for each Systems Engineering and internal artefact. For each artefact, roles are defined and filled, teams and decision-making bodies are established.

Multiple workshops were held in this process to discuss roles, role assignment and their impact on the Systems Engineering artefacts. The results of the workshops are consistent with the RAM. The team staffing is consistent with the finding as well as, as Systems Engineering Teams on lower system levels consist of a Technical Manager, System Architect, Project Leader and a Requirements Engineer. The other roles are only partly filled for higher system levels of defined and system overlapping roles.

6. Conclusion

Based on a literature review, representative Systems Engineering roles and Systems Engineering artefacts were identified. Within a RACI scheme, the identified artefacts and roles were linked and different team's compositions for the roles were derived, based on a cluster analysis. The responsibility assignments of the Systems Engineering roles have been discussed and evaluated in the context of an industrial project as well as proven by a fundamental literature review.

https://doi.org/10.1017/pds.2022.190 Published online by Cambridge University Press

With the paper at hand, Systems Engineering transformation processes and the initial set-up of Systems Engineering in an organisation are supported. Firstly, all relevant Systems Engineering artefacts are identified, secondly a recommendation for a responsibility assignment for the artefacts is given and lastly a proposition for the assignment of the Systems Engineering roles to specific teams is given.

Further work can on the one hand be performed on the refinement of the RACI scheme into a RASCI scheme, by dividing the "consulted" into "consulted" and "supported". On the other hand, can the resulting responsibility assignment matrix can be analysed towards the distance of the artefacts, not the roles. Therefore, conclusions of the groupings and clustering of the artefacts can be drawn.

References

Costello, Tom (2012): RACI—Getting Projects "Unstuck". In: *IT Prof.* 14 (2), 64-63. https://dx.doi.org/10.1109/MITP.2012.41.

Gräßler, Iris (2015): Umsetzungsorientierte Synthese mechatronischer Referenzmodelle. Implementation-oriented synthesis of mechatronic reference models. In: Fachtagung Mechatronik 2015. Dortmund, pp. 167–172.

Gräßler, Iris; Hentze, Julian; Oleff, Christian (2018): Systems Engineering Competencies in Academic Education. An industrial survey about skills in Systems Engineering. In: IEEE (Hg.): 13th System of Systems Engineering Conference. Paris, 2018. IEEE, pp. 542–547. https://ieeexplore.ieee.org/document/8428741

Gräßler, Iris; Oleff, Christian; Hentze, Julian (2019): Role Model for Systems Engineering Application. In: Design Society (Hg.): International Conference on Engineering Design 2019, Bd. 1. International Conference on Engineering Design 2019. Delft, 05.-08.08., pp. 1265–1274.

Gräßler, Iris; Pottebaum, Jens (2021): Generic Product Lifecycle Model: A Holistic and Adaptable Approach for Multi-Disciplinary Product–Service Systems. In: *Applied Sciences* 11 (10), pp. 4516. https://dx.doi.org/10.3390/app11104516.

Gräßler, Iris; Pottebaum, Jens (2022): From Agile Strategic Foresight to Sustainable Mechatronic and Cyber-Physical Systems in Circular Economies. In: Dieter Krause und Emil Heyden (Hg.): Design Methodology for Future Products. Cham: Springer International Publishing, pp. 3–26.

Gräßler, Iris; Wiechel, Dominik; Pottebaum, Jens (2021): Role model of model-based systems engineering application. In: *IOP Conf. Ser.: Mater. Sci. Eng*. 1097 (1), S. 12003. https://dx.doi.org/10.1088/1757-899X/1097/1/012003.

Haberfellner, Reinhard (2012): Systems Engineering. Grundlagen und Anwendung. 12., Zürich: Orell Füssli.

Jacka, J. Mike; Keller, Paulette J. (2009): Business process mapping workbook. Improving customer satisfaction. Hoboken, N.J: Wiley., https://onlinelibrary.wiley.com/doi/book/10.1002/9781119198406.

NASA (2007): NASA Systems Engineering Handbook. Washington D.C.: United States Government Printing Office (rev1).

Selig, Christoph J.; Baltes, Guido H. (2017): Clarifying the roles in corporate entrepreneurship. In: 2017 International Conference on Engineering, Technology and Innovation (ICE/ITMC)., Funchal, 2017: IEEE, pp. 879–887.

Sheard, Sarah A. (1996): Twelve Systems Engineering Roles. In: Proceedings of the INCOSE Sixth Annual International Symposium. Systems Engineering: Practices and Tools., Boston, Massachusetts, USA 2009: Systems Engineering Guidebook for Intelligent Transportation Systems.

Tealeb, Ahmed; Awad, Ahmed; Galal-Edeen, Galal (2016): Towards RAM-Based Variant Generation of Business Process Models. In: Alex Norta, Walid Gaaloul, G. R. Gangadharan und Hoa Khanh Dam (Hg.): Service-oriented computing - ICSOC 2015 workshops, Goa, India, 2015, Berlin, Heidelberg: Springer (Services science, 9586), pp. 91–102.

United States Department of Defense (2001): Systems Engineering Fundamentals. Hg. v. Department of Defence - Systems Management College. Fort Belvour, Virginia.

Walden, David D.; Roedler, Garry J.; Forsberg, Kevin; Hamelin, R. Douglas; Shortell, Thomas M. (2015): Systems engineering handbook. A guide for system life cycle processes and activities. Hoboken, New Jersey: Wiley.

Whitcomb, Clifford A.; White, Corina; Khan, Rabia; Grambow, Dana; Velez, Jose; Delgado, Jessica (2017): The U.S. Department of Defense Systems Engineering Competency Model. In: *INCOSE International Symposium* 27 (1), pp. 214–228. https://dx.doi.org/10.1002/j.2334-5837.2017.00355.x.

White, Corina; Whitcomb, Clifford A.; Khan, Rabia; Grambow, Dana; Delgado, Jessica; Vélez, José G. (2016): Development of a Systems Engineering Career Competency Model for the U.S. Department of Defense. In: *INCOSE International Symposium* 26 (1), pp. 1864–1874. https://dx.doi.org/10.1002/j.2334-5837.2016.00266.x.