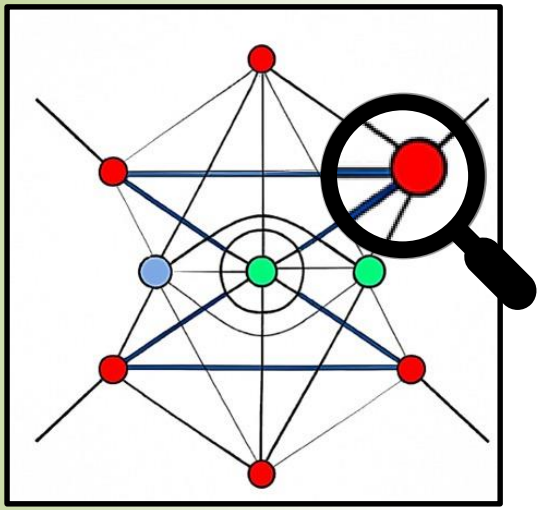

Evaluation of different Systems Engineering Approaches as Solutions to Cross-Lifecycle Traceability Problems in Product Development: A Survey

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Résumé

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Evaluation of different Systems Engineering Approaches as Solutions to Cross-Lifecycle Traceability Problems in Product Development: A Survey (MODERN SYSTEMS 2023, Valencia, Spain)

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Résumé

- Academic researcher at the University of Wuppertal, Product Safety and Quality Research Group

- Project AgiCSA: Development of new Chamical protective suits with improved ergonomic quality [1]

Content

- Introduction
- Traceability and System Engineering
- Traceability Challenges and Problems
- Research Design
- Results
- Conclusion
- References

Introduction

- **What is a system?**

  Set of objects that are in a holistic context and can be distinguished from their environment by the relationships that exist between them [2].

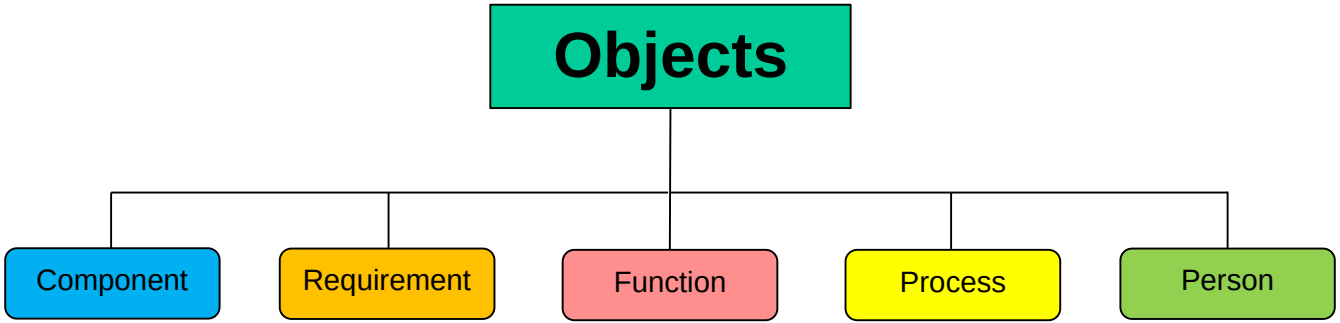


Fig.1: Different elements of a system [3]

Introduction

- **Requirement Engineering (RE)**

  Iterative elicitation, analysis, management and documentation of requirements [4].

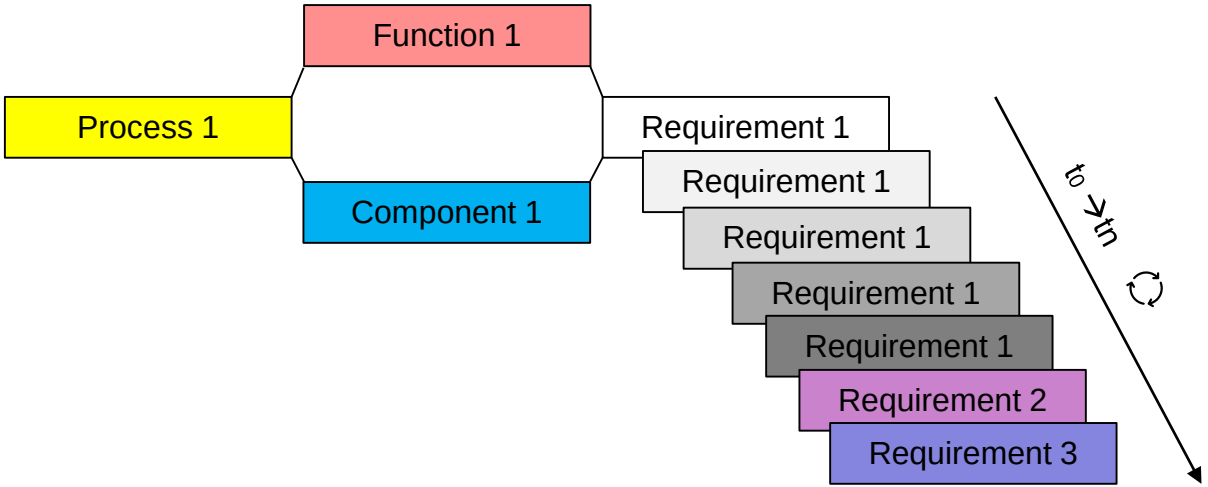


Fig.2: Changes in requirements during the development life cycle

Traceability and System Engineering

- **Traceability**

  Linking the system objects to track them throughout the system lifecycle, both backward and forward

- **System Engineering (SE)**

  “Enabling the capture and fulfillment of customer and stakeholder requirements for the system throughout the lifecycle by better traceability of issues and more efficient coordination across an interdisciplinary team.” [5]

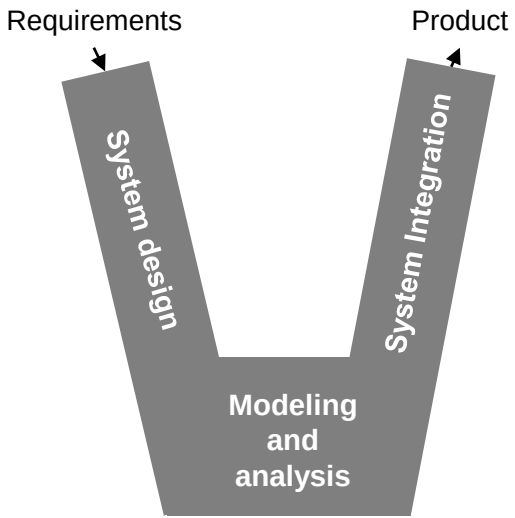


Fig. 3: V-Model

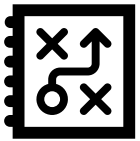
Traceability and System Engineering

- **How does SE enable the traceability?**

  - It employs "systems thinking" to break down complex issues into components, creating a purpose-driven model. → **System Model**

  - This model guides an interdisciplinary, standardized approach to solve complex tasks through logical step connections. → **Procedure concept** [3]

Tool

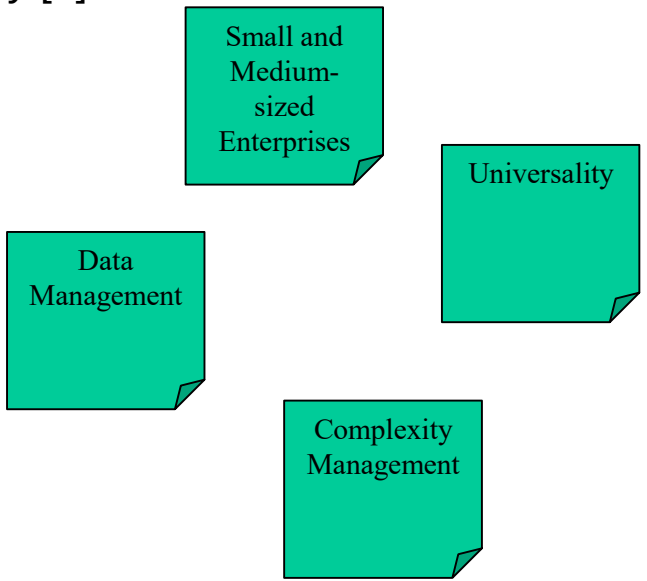


Method

Traceability Challenges and Problems

- **Method:**
  1. Methods complexity
  2. Trade-off between cost (including time) and quality [6]

- **Tool:**
  1. Tool complexity
  2. Tool capability [7]



Traceability Challenges and Problems

- **Different SE aproaches**

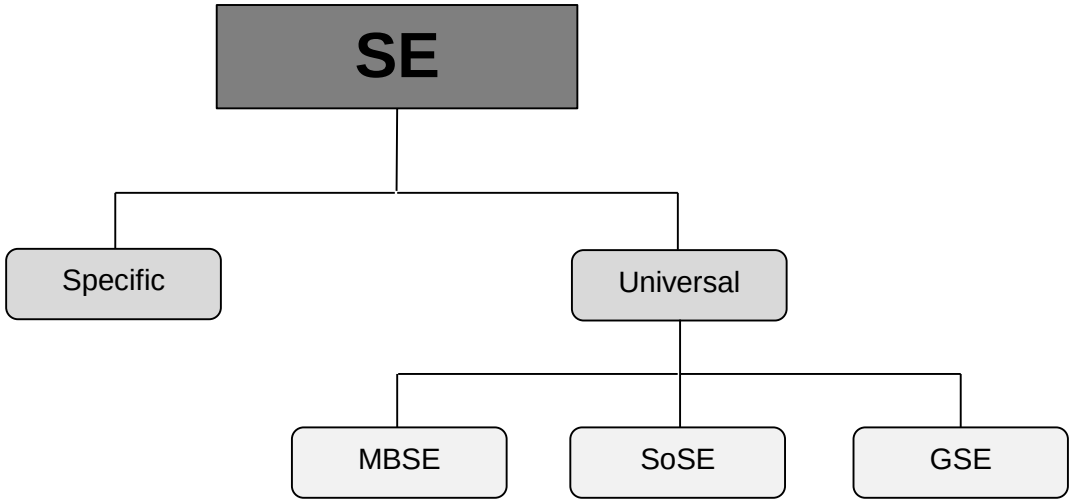


Fig.4: Division of SE into specific and universal approaches [8]

Traceability Challenges and Problems

- **Generic System Engineering**
  - Developed by Winzer and Sitte [9]
  - It proposes a common thinking model to derive a unified system model.
  - It consists of a standardized approach, which is divided into the "analysis" (problem identification and system analysis), the “Goal setting" (problem localization) and the "design" (recommendations)

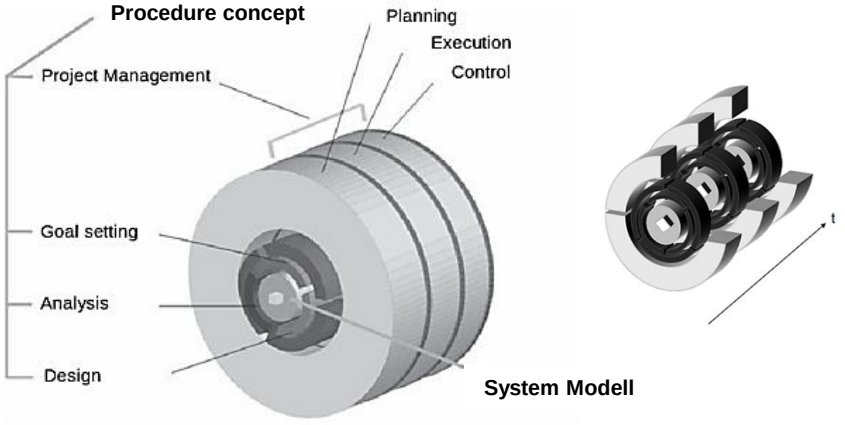


Fig.5: Generic System Engineering [9]

Traceability Challenges and Problems

- **e-DeCoDe**
  - enhanced Demand Compliant Design [11]
  - A technique for system definition, description, modeling, and progressive refinement
  - Matrix-based connection of the system elements

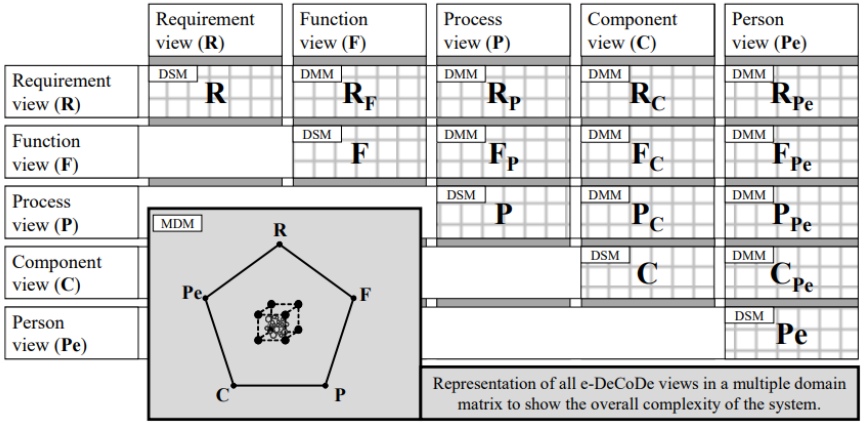


Fig.6: Generic System Engineering [10]

Traceability Challenges and Problems

- **SoSE**
  - No universally accepted definition for SoS/SoSE
- **MBSE**
  - No Common language for defining stakeholder needs and bringing them into a single model
  - High implementation costs
  - Interaction between the system model and the procedure model
- **GSE**
  - Lack of integration of test processes in the model

Research Design

Research Questions

- Q1: Which approach is able to define the system more comprehensively?
- Q2: Which approach is focused on managing complexity through a universal modeling methodology applicable in transdisciplinary teams?
- Q3: Which approach establishes the link between requirements and testing?
- Q4: Which approach has a structured procedure concept connected to the system model that maps the lifecycle of a system?
- Q5: Which programs/tool can contribute better to reducing complexity?
- Q6: To what extent are the necessary information available to the system developer during system development?

Research Design

Topic Area

- T1: System Definition and Delimitation
- T2: System Modeling
- T3: Integration of Test cases
- T4: Structured Procedure Concept
- T5: Model Implementation
- T6: System Information Integration

T_1 (System Definition and Delimitation): The approach developed shall primarily address the linkage of requirements *(1p)* to key system parts and artifacts, including processes *(1p)* and components *(1p)*. Functional requirements shall be linked to the corresponding functions *(1p)* that the system is intended to perform. The approach should provide a clear boundary between the system and the environment and methodically support their interaction. To enable the treatment of requirements in EN, the approach should also include roles and liability through a person view *(1p)*.

T_5 (Model Implementation): As already mentioned, the model should be implemented in a suitable software tool to realize system modeling *(1p)*. The program must visibly and transparently represent the system elements and their interrelationships *(1p)*. In addition, it must have filtering and focusing functions that enable concentration on the essentials or certain elements and thus systematically reduce the complexity of the modeled system *(1p)*. Even more, the software must enable the time-logical arrangement of functions and processes *(1p)* as well as the storage of system states in order to be able to track phases of project management *(1p)*.

Fig.7: Examples of evaluation criteria

Result

Methodology

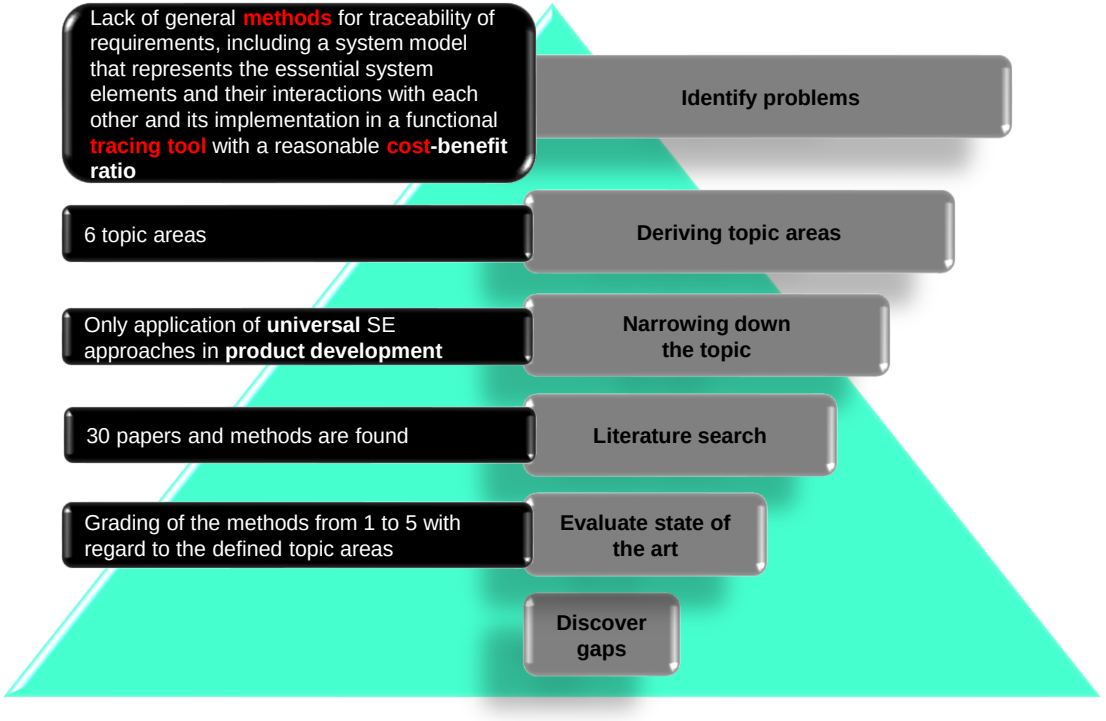


Fig.8: Methodology of the survay

Result

No.	Author	Year	T_1	T_2	T_3	T_4	T_5	T_6
			MBSE					
1	(Plateaux et al. 2020)	2020	4	2	3	3	3	0,5
2	(Arockia Irudayaraj 2020)	2020	4	3	3	1	3	1,5
3	(P. Ciampa et al. 2020)	2020	5	3	2	2	3	0
4	(Huang et al. 2022)	2022	4	3	3	0	3	1
5	(Gebreyohannes et al. 2020)	2020	4	3	2	3	3	1
6	(Subarna et al. 2020)	2020	5	3	2	3	3	0
7	(Bougain und Gerhard 2020)	2020	3	2	1	4	5	4
8	(Pessa et al. 2016)	2016	5	3	2	5	4	1
9	(Bougain und Gerhard 2017)	2017	3	2	1	4	5	4
10	(Marshall et al. 2017)	2017	3	3	3	5	3	1
11	(Bruggeman et al. 2022)	2022	3	2	3	5	2	3
12	(Bursac 2016)	2016	3	3	0	2	3	1
13	(Huth et al. 2017)	2017	5	3	3	3	2	2,5
14	(Roßmann et al. 2017)	2017	4	3	4	1	1	2
15	(Berges et al. 2022)	2022	3	2	0	0	3	1
16	(Kremer et al. 2020)	2020	5	4	3	4	3	4
17	(Jackson und Wilkerson 2016)	2016	2	3	0	1	2	2
18	(Brahmi et al. 2021)	2021	2	3	1	1	2	1
19	(Tsui et al. 2018)	2018	5	1	3	3	3	2,5
20	(Suryadevara und Tiwari 2018)	2018	4	2	0	2	4	0
21	(Mandel et al. 2021)	2021	4	4	4	4	3	5
22	(Steimer et al. 2017)	2017	4	4	4	5	2	4
23	(Lukei et al. 2016)	2016	3	0	0	4	3	1
24	(Windisch et al. 2022)	2022	4	4	3	1	5	1
			GSE					
25	(Mistler et al. 2021a)	2021	5	5	0	3	4	2
26	(Schlüter et al. 2019)	2019	5	5	0	4	4	2
27	(Bielefeld et al. 2018)	2018	4	5	0	4	4	2
			SoSE					
28	(Melanie L. Grande 2020)	2020	2	2	0	3	3	1
29	(Knöös Franzén et al. 2019)	2019	2	2	0	2	3	0,5
30	(Power et al. 2021)	2021	2	2	0	3	2	1

Conclusion

- Limitations in terms of generic model structure
- Not complete consideration of the important system elements
- Absence of the person view, which complicates the traceability of responsibilities
- Integration of the test processes into the system model
- Integration of the necessary information
- Compared to the MBSE and GSE approaches, the SoSE-based methods have reached the lowest score with regard to the observed topics.

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Thank you so much for your attention ☺