Barriers to Successful Embedding of Systems Engineering into Organizations

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The landscape of industry is evolving rapidly, presenting formidable challenges in the development of complex technical products. Systems Engineering (SE) emerges as a promising solution to tackle these challenges. In recent years, the awareness and significance of SE have surged within industry sectors such as automotive, railway, aerospace, and defense. However, the actual embedding of SE into organizational frameworks poses a significant challenge for many companies operating within these sectors and others.

Introducing SE entails not only dealing with technical complexity but also significant human aspects of change which are critical to ensuring stakeholder engagement, smooth adoption, and the long-term success of the initiative. Various impacts of change, including restructuring, reengineering, and cultural shifts, must be addressed through effective change management techniques to ensure successful SE integration.

This article aims to delve into the complexities surrounding the embedding of SE into organizations. By examining the struggles encountered by companies, we seek to uncover the underlying reasons behind these challenges. Expectations towards SE are scrutinized, and an analysis of the barriers hindering its adoption is presented, drawing insights from the experiences of two non-participating customers. Additionally, we outline ten essential requirements crucial for the successful

embedding of SE, comparing them with available introduction methodologies.

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Industrial Challenges

Systems Engineering (SE) offers an approach to handle complexity. Despite these potential benefits in product development, the adoption of SE varies significantly by industry, being more prevalent in the aerospace, defense, and automotive sectors than in other areas. Furthermore, SE is more commonly used in large corporations than small and medium-sized enterprises (SMEs). SMEs face challenges in accessing and building SE expertise due to limited resources and varying SE needs depending on the specific projects and

applications of each SME.

The complexity of products and their development is rising due to trends like digitalization, globalization, and sustainability. Companies are encountering new hurdles as they transition from traditional mechatronic products to autonomous, interactive, and dynamically networked systems. This shift, along with the increasing interdisciplinarity of their systems and enhanced networking with other systems, contributes to the escalating complexity in product development.

While SE is a holistic approach to address such challenges, its adoption remains relatively nascent within organizations. Historically, development approaches have been discipline-oriented, lacking the systemic perspective required for tomorrow's products. Consequently, the introduction of SE presents a formidable challenge, given the established discipline-centric mindset prevalent in all industries and application domains.

A Holistic Approach

The Capability Model approach recognizes that building a lasting organizational capability requires more than process and tools. As illustrated in the Figure 1 below, the elements that build up a SE organizational capability include Governance, Organisation, Process, Process support, Information and Technology & Infrastructure.

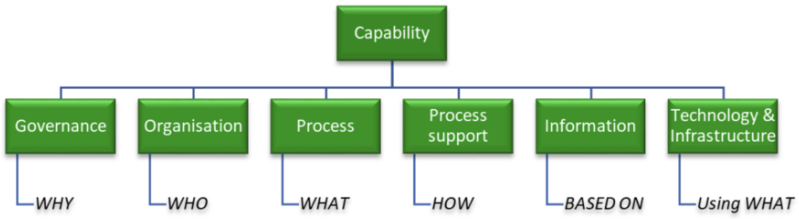

Figure 1. The Capability Model (Strandberg, et al, 2024).

Furthermore, the level of organizational capability needed should be based on the context in which it operates. The contextual factors can be divided into Business, Organizational and Product related aspects as shown in Figure 2.

A capability the ability of an entity (department, organization, person, system) to achieve its objectives, specifically in relation to its overall mission. Only when this is used in business operations will the desired effects, such as improved quality, reduced lead-times

and enhanced cost-effectiveness, be realized.

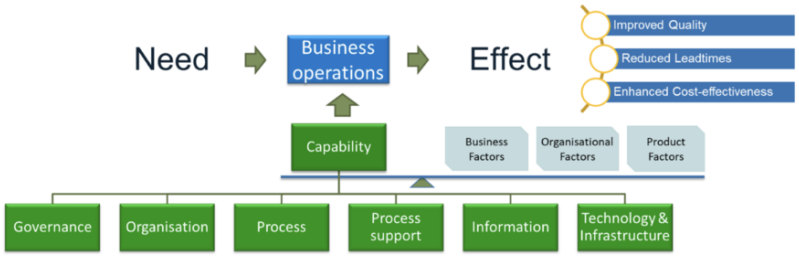

Figure 2. The Capability Model with Contextual Factors
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Implementation of recognized SE standards

Any embedding of SE in an organization should start with a formulation of the Why. As illustrated in the Capability Model, this falls under the Governance element. One common approach involves the tailoring and implementation of recognized standards, such as those outlined by the International Organization for Standardization (ISO). This strategic framework outlines the essential steps involved in implementing SE standards as shown in Figure 3, offering organizations a roadmap for success.

Figure 3. The essential steps involved in implementing SE.
(SEBoK Original)

Step 1: Planning for Success

The first stage in implementing an SE standard is thorough planning to ensure smooth integration. This phase includes:

- To understand the current maturity of the organization, baselining what is done or not done and then considering how you might effectively implement.
- Identifying the appropriate industry standards that the organization will seek to comply with and the level of capability desired. Many of these standards describe a list of activities to be performed by an organization and its projects to demonstrate the capability.
- Identifying gaps and areas of non-compliance by mapping current activities against the established activities within the standards for the capability to be achieved.
- Evaluating the necessary process and organizational changes for successful embedding of SE.
- Securing commitment and support from organizational leadership for the resources required (and maintaining this commitment throughout the implementation process).

Step 2: Resource Allocation and Management

Proper resource allocation is critical for successful SE standard implementation. This step involves:

- Appointing a dedicated SE standard implementation manager to oversee the process and ensure timelines and objectives are met.
- Developing a detailed resource plan and schedule, outlining the allocation of personnel, finances, and technological infrastructure needed for SE implementation.
- Gaining approval from organizational leadership for funding and scheduling to ensure smooth execution of the implementation plan.

Step 3: Preparation and Training

Preparing the organization for embedding of SE requires effective communication and comprehensive training

initiatives. This phase includes:

- Creating a communication and training plan to disseminate information about SE standards and build organizational readiness.
- Updating organizational policies, procedures, and work instructions to incorporate new SE tasks and methodologies.
- Conducting training sessions at all levels of the organization to provide personnel with the necessary knowledge and skills for SE implementation.

Step 4: Implementation and Auditing

The implementation phase involves systematically executing SE standards, with ongoing monitoring and evaluation. Key activities include:

- Implementing one action or item at a time to ensure gradual and sustainable integration.
- Performing regular audits to assess adherence to SE standards and identify areas for improvement.

Step 5: Evaluation and Feedback

Evaluating the effectiveness of SE implementation is essential to understand its impact and identify opportunities for refinement. This phase involves:

- Managing schedules and resources to facilitate thorough reviews of newly implemented standard tasks.
- Informing the organization upon project completion, highlighting achievements, and outlining future milestones.

Requirements for SE Introduction

The successful embedding of SE into organizational workflows requires careful consideration of various factors and adherence to specific requirements. The integration of SE standards serves as a cornerstone for organizations aiming to optimize their engineering processes and deliver high-quality products and services to market.

By adhering to established standards and best practices,

companies can effectively navigate the complexities of modern engineering challenges while ensuring consistency, reliability, and efficiency across all facets of their operations. However, the journey towards SE integration is not without its challenges, as organizations must navigate a myriad of considerations to ensure successful implementation.

As we explore the nine crucial requirements for embedding of SE outlined below, it becomes evident that a strategic and holistic approach is essential for realizing the full potential of SE within an organizational context:

1. Create the vision and roadmap for embedding of SE
2. Providing a flexible implementation strategy tailored to organizational needs.
3. Providing comprehensive support for SE rollout within organizations.
4. Incorporating change management strategies into SE implementation efforts.
5. Tailoring SE considering the characteristics of companies or organizations (first level of tailoring).
6. Implementing SE through both top-down and bottom-up approaches.
7. Introducing tailoring to adapt SE approaches to specific project requirements (second level of tailoring).
8. Integrating SE with Model-Based Systems Engineering (MBSE).
9. Ensuring the selection of a tool or tools that meet your needs in terms of processes and methods.

Barriers for Organizations

While the adoption of standardized best practices as provided by ISO standards lays a solid foundation for embedding of SE within organizations, the journey is often fraught with challenges and barriers that must be navigated with precision and foresight.

From rigid organizational structures to cultural resistance and the nebulous nature of quantifiable benefits, each barrier presents unique challenges that must be addressed to ensure the successful integration of SE within organizational workflows.

By understanding and addressing these barriers head-on, organizations can navigate the complexities of SE

integration with confidence and precision, unlocking the full potential of standardized methodologies to drive innovation, efficiency, and competitiveness in today's dynamic business landscape.

Rigid Organizational Structures

The inherent rigidity of organizational structures poses a significant obstacle to SE integration, hindering the necessary adaptations and restructuring required to accommodate new methodologies and approaches.

Slow Decision-Making Processes

Delays in decision-making processes impede the timely implementation of SE methodologies, prolonging the transition and inhibiting organizational agility and responsiveness.

Resistance to Change

Cultural resistance and entrenched silo thinking contradict the holistic principles of SE, necessitating a fundamental cultural shift and fostering a culture of collaboration and cooperation across organizational boundaries.

Specialization Challenges

While specialization is essential for complex product development, it can complicate the internal allocation of SE roles, which often require a more generalized skill set and interdisciplinary collaboration.

Non-Quantifiable Benefits

The intangible nature of SE benefits, coupled with a lack of key performance indicators (KPIs) to substantiate its efficacy, poses significant challenges to its adoption and integration within organizations.

Insufficient Provision of Resources

Inadequate provision of introduction methods, expertise, and resources further complicates the adoption and successful implementation of SE methodologies, undermining the effectiveness of integration efforts.

Neglecting Non-Technical Aspects

Overlooking non-technical aspects such as stakeholder needs and inadequate change management strategies can undermine the success of SE integration efforts, emphasizing the importance of a holistic and comprehensive approach.

Lack of skilled professionals

One of the major barriers to integrating SE in an organization is the shortage of well-trained and professionally competent personnel in this field. The absence of qualified experts hinders the effective implementation of SE methods and tools, which can slow down projects and impact the quality of outcomes.

Conclusion

Embedding of SE into organizations requires a holistic approach, covering both establishing the appropriate level of capability and the careful implementation thereof.

While the adoption of established SE standards provides a solid foundation for integration, organizations must also recognize the need to tailor these approaches to suit their specific project requirements and organizational objectives. By combining standardized methodologies with bespoke strategies tailored to their unique needs, companies can leverage the full potential of SE to drive value creation and achieve sustainable competitive advantage.

In conclusion, the successful embedding of Systems Engineering into organizations requires a multifaceted approach addressing technical, cultural, and organizational challenges. By understanding and addressing these barriers, companies can unlock the full potential of SE to drive innovation and achieve sustainable growth.

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