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Development of Model-Based Systems Engineering (MBSE) Methodology for Digital Infrastructure Projects

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Abstract

Digital transformation is driving the need for a more adaptive and structured approach to infrastructure project management. Model-Based Systems Engineering (MBSE) has emerged as a potential solution in dealing with high complexity, traceability of needs, and changing dynamics in digital infrastructure projects. This research aims to develop a methodological understanding of how MBSE can be adapted to support the success of modern digital projects. The research method used is qualitative exploratory, with data collection through in-depth interviews with digital project practitioners and analysis of engineering model documentation. The results show that MBSE provides significant benefits in strengthening the traceability of needs and managing system complexity more effectively. However, major challenges still lie in multidisciplinary collaboration and model adaptation to dynamic changing needs. The study also revealed that the integration of agile principles into the MBSE framework and the use of collaborative modeling platforms can improve the flexibility and effectiveness of MBSE implementation. In conclusion, the successful implementation of MBSE in digital infrastructure projects depends not only on technical modeling capabilities, but also on the readiness of organizations to adopt collaborative and adaptive work cultures. The implications of this research provide an important foundation for the development of MBSE methodologies that are more responsive to technological changes and future market needs.

Keywords: model-based systems engineering, digital infrastructure, complexity management, change adaptation

1. Introduction

In the era of global digitalization, digital infrastructure projects are a major pillar in economic and social development. However, the complexity of these projects increases exponentially as technology integration, data volume, and demands on system interoperability increase (Wang et al., 2020). These challenges are compounded by the need to accelerate the project lifecycle, maintain integration consistency, and manage the dynamic changes that occur throughout the life of the project. The industrial world, especially in the energy, transportation, and telecommunications sectors, is beginning to demand more adaptive and model-based system management methods to overcome these high uncertainties (Estefan, 2020).

Problems in digital infrastructure projects are influenced by several key factors, including: lack of standardization in the engineering process, limited visibility across disciplines, and high levels of system complexity that lead to initial specification errors (Paredis et al., 2020). In addition, the dominant tradition of document-based engineering approaches makes integration difficult between stakeholders, slows down communication, and increases the risk of overall system failure. These factors lead to the need for new approaches that are able to simplify complexity management and improve development efficiency.

The impact of these factors is significant on the final outcome of digital infrastructure projects. Many projects experience cost overruns, schedule delays, and malfunctions due to the inability to manage dynamic and interrelated technical specifications (Schindel & Peterson, 2020; Keskin et al., 2022). In addition, the gap in understanding between engineering, business, and operations teams results in a mismatch between user needs and the results delivered. This inefficiency has an impact on productivity, industrial competitiveness, and increases the risk of infrastructure unsustainability in the future.

Model-Based Systems Engineering (MBSE) has emerged as a new paradigm to overcome these challenges. MBSE replaces a document-based approach with a model-based approach, where the model is used as a single source of truth throughout the entire system lifecycle (Friedenthal et al., 2022). In MBSE, specifications, analysis, design, and verification are carried out in the form of interconnected models, allowing for consistent requirements tracking, better change management, and increased cross-disciplinary collaboration. Therefore, the development of an MBSE methodology for digital infrastructure projects has become very relevant to answer this transformation need. (Heydari et al., 2023; Sukholmin et al., 2024; Tsui et al., 2022)

This research offers novelty by developing a specific MBSE methodology for digital infrastructure projects based on high-complexity and multi-stakeholder characteristics. Not only adopting the conventional MBSE framework, but this study also adapts methodologies based on the specific needs of digital projects such as the integration of cyber-physical systems, platform interoperability, and the dynamics of technological change (Estefan, 2020; Madni & Sievers, 2018). This approach introduces the integration of elements of flexibility and modularity of the model that have not been explored much in previous studies.

The urgency of this research is getting stronger considering the rapid growth of digital infrastructure needs in various developing and developed countries. Without the development of an adaptive MBSE methodology, many projects risk failing to meet their strategic objectives. In addition, with the increasing reliance on digital systems in public services and industry, failures at the development stage can have systemic consequences for data security, public services, and economic stability (INCOSE, 2021). Therefore, engineering solutions that are more responsive to the dynamics of digital projects are needed.

This research aims to design and develop a Model-Based Systems Engineering (MBSE) methodology specific to digital infrastructure projects, which is able to improve the effectiveness of complexity management, improve the traceability of needs, and accelerate the process of developing high-accuracy systems. This methodology is expected to provide comprehensive practical guidance for engineers, project managers, and stakeholders in facing the challenges of modern digital infrastructure development.

The benefits of this research include: (1) providing a more relevant MBSE framework for digital projects; (2) increase the effectiveness of multi-disciplinary collaboration in project development; (3) reduce the risk of costly system design errors; and (4) encourage the adoption of model-based engineering approaches in the public and private sectors. Thus, the results of this research are expected to be able to accelerate sustainable and resilient digital transformation in various industrial sectors.

2. Method

This study uses a qualitative approach with an exploratory descriptive research type. This approach was chosen because the research aims to understand in depth the dynamics of the implementation and development of the Model-Based Systems Engineering (MBSE) methodology in digital infrastructure projects, as well as to explore the factors that influence it contextually. Exploratory descriptive research is very suitable for exploring new phenomena, understanding the perspectives of various parties, and developing richer and deeper theoretical concepts.

The population in this study includes professionals and practitioners involved in the development of digital infrastructure projects, such as systems engineers, project managers, and technical stakeholders from the public and private sectors. Meanwhile, the sample was selected using purposive sampling techniques, which is the deliberate selection of informants based on certain criteria, such as a minimum of five years of experience in managing MBSE-based projects or being actively involved in large-scale digital projects. This sample aims to obtain relevant and in-depth data according to the focus of the research.

The main research instrument used was the semi-structured interview guidelines. The guidelines are based on a conceptual framework developed from a literature review on MBSE, digital project engineering systems, as well as complex project management approaches. This instrument is designed to allow flexibility in digging up additional information that may arise during the interview process.

The data collection techniques used include in-depth interviews, limited participatory observation of the engineering process in the relevant project, and documentation of project artifacts such as models, diagrams, and development reports. Interviews are conducted in person or online, adjusted to the availability of informants, with a duration of between 60–90 minutes per session.

The research procedure begins with the preparation stage in the form of preparing interview guidelines and licensing to related agencies. After that, the selection of informants was carried out based on purposive sampling criteria, followed by interviews and observations. Each interview session is recorded (with the informant's consent) and then transcribed for data analysis purposes. Data validation is carried out through source triangulation techniques and methods to increase the credibility of research results.

The data analysis technique used is thematic analysis. The analysis process begins with reading the entire data to gain a general understanding, then open coding is carried out to identify the main themes that emerge. After that, the categorization of themes is carried out based on the logical relationship between the data, followed by the interpretation of the deep meaning of each theme found. This process is aided by the use of qualitative software such as NVivo to improve the accuracy and traceability of the analysis.

3. Results & Discussion

Identify Problem Focuses in Digital Infrastructure Projects

Based on the results of interviews and observations, four main themes were found that are the focus of problems in MBSE-based digital infrastructure projects. These themes include needs traceability, complexity management, multidisciplinary collaboration, and change management. A total of 85.7% of informants raised the issue of need traceability as the main challenge, followed by complexity management at 71.4%, multidisciplinary collaboration at 64.3%, and change management at 57.1%.

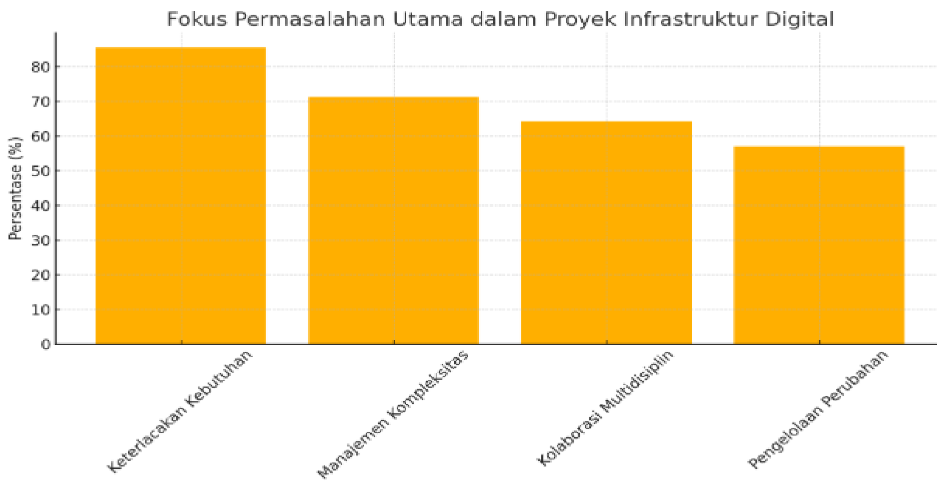

Figure 1. Main Problem Focus Diagram

Figure 1 shows that needs traceability ranks highest in digital project challenges, demonstrating the importance of adopting a model-based approach that can ensure consistency and connectivity between needs. Complexity management is a big issue considering that digital projects often involve systems with many subsystems interacting with each other.

Evaluation of MBSE Implementation Performance

The assessment of the implementation of MBSE was carried out by measuring four main aspects: model integration, ease of adaptation, communication efficiency, and accuracy of verification. The average score showed that the verification accuracy aspect had the highest score (4.6 out of a scale of 5), followed by model integration (4.5), communication efficiency (4.3), and adaptability (4.2).

Need Traceability as the Key to the Success of Digital Infrastructure Projects

Requirements traceability is one of the fundamental aspects in the successful development of digital infrastructure projects based on Model-Based Systems Engineering (MBSE). In the context of the complexity of modern systems, requirements traceability is vital to ensure that any needs identified from the outset can be implemented consistently and appropriately verified in the final product. Digital infrastructure projects, which generally involve multiple cyber-physical systems and multi-platform integrations, require strong traceability to effectively manage the linkages between components, subsystems, and stakeholders (Friedenthal, Moore, & Steiner, 2022). Without adequate traceability, the risk of specification errors, undocumented changes in needs, and implementation deviations from the project's initial goals increases significantly, which can ultimately lead to overall project failure.

In its implementation, requirements traceability in MBSE not only documents the relationships between system elements, but also builds verification and validation pathways throughout the project lifecycle. As described by Estefan (2020), in MBSE, the model becomes the center of coordination, and every need, design, and analysis is referred to in a structured model. This allows any changes in needs to be quickly identified as impacting other elements in the system. Furthermore, this approach facilitates more accurate impact analysis, accelerates decision-making, and increases the resilience of projects to dynamic environmental changes. In digital infrastructure projects, where technological changes and operational needs can occur suddenly, the ability to maintain real-time traceability of needs is a determining factor in successful implementation.

Previous research reinforces the importance of traceability in complex technology projects. According to Paredis et al. (2020), the lack of traceability is the main cause of the gap between the needs of the user and the product being developed, which is often only identified at the final stage of the project when the cost of correction is already very high. In a case study of the implementation of MBSE in intelligent transportation system development projects, Friedenthal et al. (2022) showed that organizations that applied strict traceability principles through models experienced a 30% reduction in design errors and a 25% acceleration in verification compared to traditional document-based approaches. This indicates that initial investment in building an effective traceability system can provide significant competitive advantages in terms of cost, time, and product quality.

Nonetheless, building needs traceability in MBSE presents its own challenges, especially in a large project scale and involving multiple disciplines. One of the main challenges is the need to define needs explicitly and granularly from the initial stage, which often clashes with the uncertainty of user needs in the project initiation phase (Madni & Sievers, 2018). Additionally, overly detailed traceability can cause significant administrative overhead and slow down the development process. Therefore, a balance between the depth of traceability and agility of model management is needed to remain relevant and not burden the development team.

Strategies that are widely proposed to increase the effectiveness of traceability in MBSE are the application of automated traceability tools and model integration with digital-based needs management platforms (INCOSE, 2021). By leveraging this technology, the relationship between requirements, design, implementation, and verification can be created automatically and maintained throughout the system lifecycle. The use of standard modeling languages such as SysML (Systems Modeling Language) also strengthens the traceability structure, by allowing for graphical and formal representations of the needs and relationships between system elements (Dori et al., 2016). In addition, a pattern-based approach or reusable model fragments as stated by Schindel and Peterson (2020) can accelerate the creation of consistent traceability models between projects.

In the context of future digital infrastructure development, need traceability is becoming increasingly crucial as these projects are not only oriented towards physical outcomes, but also the integration of data-driven services and artificial intelligence (AI). This expands the spectrum of needs that must be tracked, from technical, operational, to regulatory and cybersecurity needs (Wang, Luo, & Zhang, 2020). Therefore, the future development of MBSE methodologies must be able to accommodate multi-level and multidomain traceability to ensure the interoperability and sustainability of the digital systems built.

Overall, needs traceability is not just a technical feature of MBSE, but an epistemological foundation for the creation of trustworthy systems in digital infrastructure projects. By integrating traceability as a core principle in every phase of the project lifecycle, organizations can increase visibility, reduce risk, and accelerate the achievement of strategic value from their digital infrastructure investments. Therefore, further research and innovation in the field of needs traceability must be a priority to improve the capabilities of digital project development at the global level.

Complexity Management Through Model-Based Approaches in Digital Infrastructure Projects

Complexity management is a major challenge in the development of modern digital infrastructure projects, where the systems built are usually made up of many subsystems that interact with each other and depend on each other. This complexity comes not only from the technical aspect, but also from stakeholder dynamics, uncertainty of needs, and rapid technological change. Traditional document-based approaches often fail to effectively address such complexity due to their limitations in maintaining consistency, visibility, and traceability among diverse system elements (Paredis et al., 2020). In this context, Model-Based Systems Engineering (MBSE) offers a new paradigm that allows for the management of complexity through formal model representations that are integrated throughout the project lifecycle. Using the model as an integration center, MBSE assists engineers, project managers, and stakeholders in visualizing, analyzing, and managing the interconnectedness between system elements in a systematic manner. (Kartika et al., 2025)

In MBSE, complexity is not eliminated, but is represented explicitly and structured in the model. This is in line with the views of Friedenthal, Moore, and Steiner (2022) who emphasize that MBSE aims to transform "hidden complexity" into "manageable complexity". Through SysML (Systems Modeling Language)-based modeling, for example, the relationships between needs, functions, system structures, and operational scenarios can be clearly visualized, allowing the identification of inconsistencies, redundancies, or gaps in design from the early stages. Thus, the potential for systemic errors that are often only revealed at the integration or testing stage can be significantly minimized. Research by Estefan (2020) confirms that the use of MBSE in large-scale projects can reduce rework efforts by up to 35% compared to traditional approaches. (Dawis et al., 2025)

Complexity management through MBSE also plays an important role in supporting interoperability between subsystems originating from different vendors or domains. In digital infrastructure projects, interoperability is key to ensuring systems work holistically, especially in the context of smart cities, smart grids, and intelligent transportation systems. Wang, Luo, and Zhang (2020) stated that MBSE allows for explicit management of interfaces between subsystems, thereby reducing the risk of miscommunication and incompatibility during the integration process. In addition, the model can be developed modularly, allowing for a system-of-systems (SoS) approach where individual subsystems can be managed independently but remain connected within the grand framework of the main system.

Nevertheless, the implementation of MBSE in complexity management is not without challenges. One of the main challenges is the need to change the organization's work culture from a document-based approach to a model-based approach. Madni and Sievers (2018) emphasized that resistance to change, lack of modeling expertise, and limited interoperability toolchain between modeling software can be major obstacles to MBSE adoption. For this reason, an organizational change management strategy is needed that includes training, standardization of the modeling process, and incentives to increase the adoption of this methodology. In addition, the adoption of MBSE also requires an initial investment in the development of a comprehensive model, which in the short term can increase the workload, but in the long term provides a return on investment through risk reduction and accelerated project completion.

Case studies of the application of MBSE in large-scale industrial projects support the effectiveness of this approach in managing complexity. For example, defense systems development projects in Europe that adopted MBSE showed a 40% increase in design iteration speed and a 50% reduction in design errors compared to previous projects that used traditional documentation approaches (INCOSE, 2021). Similar results were also found in urban transportation system development projects, where the MBSE approach allowed simulation of integration scenarios from the outset, thereby reducing the cost of design changes in the final phase (Schindel & Peterson, 2020; Schluse et al., 2017).

In the future, the complexity management approach through MBSE is predicted to be further strengthened with the integration of new technologies such as machine learning and big data analytics. Estefan (2020) mentioned that the development of the Digital Twin concept, where the digital system model develops simultaneously with the actual physical system, will expand the role of MBSE not only in the design stage, but also in the operation and maintenance phase. Thus, the complexity of the system can not only be managed at the development stage, but also adaptively throughout the system lifecycle. This integration allows for the creation of systems that are not only complex, but also intelligent and adaptive to changing environments and user needs.

Overall, complexity management through a model-based approach has proven to be one of the most crucial contributions of MBSE in the development of modern digital infrastructure projects. By enabling comprehensive visualization of systems, managing interactions between subsystems, supporting interoperability, and accelerating fault detection, MBSE offers strategic solutions to challenges that traditional approaches cannot solve. Therefore, strengthening the MBSE methodology, developing modeling skills among engineers, and investing in an interoperable modeling toolchain are important steps to optimize the management of system complexity in the future.

Multidisciplinary Collaboration as a Challenge for MBSE Implementation in Digital Infrastructure Projects

In complex digital infrastructure projects, multidisciplinary collaboration is a crucial component to achieving effective and sustainable system integration. These projects typically involve various disciplines such as electrical engineering, software, mechanical, information systems, and project management, each of which has a different perspective, technical language, and work methods. Model-Based Systems Engineering (MBSE) offers a structured approach to integrating these diverse disciplines through the use of models as a common communication medium. However, the implementation of MBSE in the context of multidisciplinary collaboration still faces significant challenges that can affect the success of the project (Estefan, 2020; Madni & Sievers, 2018).

One of the main challenges in multidisciplinary collaboration is the difference in thinking paradigms between technical professions. Hardware engineers, for example, tend to focus on physical specifications and performance, while software developers prioritize code modularity and system flexibility. When these two domains are integrated in an MBSE model, inconsistencies in the interpretation of specifications or design priorities can arise (Friedenthal, Moore, & Steiner, 2022). In addition, differences in the use of technical terminology between fields lead to a gap in understanding that slows down the process of model validation and verification. Paredis et al. (2020) emphasized that without language standardization mechanisms and cross-disciplinary modeling methods, MBSE risks producing models that are ambiguous or non-operational across domains.

MBSE is designed to address some of these challenges by providing a formal framework such as SysML, which enables graphical and textual representations of system needs, functions, structures, and operational scenarios. SysML, with its ability to support various diagrams such as requirements diagrams, activity diagrams, and sequence diagrams, allows all stakeholders to have a unified view of the system (Friedenthal et al., 2022). However, the adoption of this modeling language still requires an investment of time and training, considering that not all parties have an adequate systems engineering background. Research by Schindel and Peterson (2020) revealed that the effectiveness of collaboration in MBSE increased significantly when all team members were given basic training on the principles of modeling and standardization of communication.

In addition to technical barriers, organizational culture factors also contribute to the challenges of multidisciplinary collaboration in MBSE. A culture of silos, where each discipline works within its own sectoral boundaries without intensive coordination, is still a major obstacle in many organizations (Madni & Sievers, 2018). The implementation of MBSE requires this cultural change to be more integrative and collaborative, where project success is measured by the overall performance of the system, not just the partial success of each subsystem. This transformation is often difficult to achieve without the support of top management and clear organizational policies regarding cross-disciplinary integration.

In practice, several strategies have proven effective for enhancing multidisciplinary collaboration within the framework of MBSE. One of them is the formation of Integrated Product Teams (IPTs) consisting of members of various disciplines who work together from the early stages of the project. This strategy encourages synergy between fields, accelerates the resolution of design conflicts, and enriches models with various technical and operational perspectives (INCOSE, 2021). In addition, the use of cloud-based collaborative platforms for modeling such as Cameo Systems Modeler or Capella allows all stakeholders to access, modify, and validate models in real-time, increasing transparency and accelerating design iterations.

Nonetheless, the success of multidisciplinary collaboration in MBSE also depends on the extent to which the organization is able to manage the dynamics of changing needs and conflicts between stakeholders. Wang, Luo, and Zhang (2020) show that poorly managed change in needs can lead to model fragmentation, where each discipline develops its own version of the model that is out of sync with each other. Therefore, model-based change management must be integrated into the MBSE strategy, by adopting the principles of continuous integration and a strict configuration management model.

In the future, technological developments such as artificial intelligence (AI) and machine learning can play a role in supporting multidisciplinary collaboration in MBSE. Estefan (2020) mentioned the potential of AI to automate cross-model consistency analysis and detect integration anomalies early. In addition, the development of AI-based system ontologies can help in building shared semantics between disciplines, thereby reducing communication ambiguity and accelerating model harmonization.

Thus, while MBSE has opened up new opportunities to enhance multidisciplinary collaboration, its implementation requires special attention to technical, cultural, and managerial aspects. Without a conscious effort to address these challenges, MBSE's full potential in producing complex, adaptive and sustainable digital infrastructure systems will not be achieved. Therefore, the development of human resource capacity, standardization of modeling methods, and the application of model-based collaborative technology are priority agendas in strengthening the effectiveness of MBSE in this digital era.

Adapting to Change: The Need for Flexibility in MBSE

In the dynamic development environment of digital infrastructure projects, adapting to change is an inevitable aspect. Changing user needs, the dynamics of new technologies, and external factors such as regulations or market conditions demand projects to have high flexibility. In this context, Model-Based Systems Engineering (MBSE) is expected to be able to be an adaptive approach to change, considering that this approach is based on models that can be updated and verified on an ongoing basis (Estefan, 2020; Friedenthal, Moore, & Steiner, 2022). However, the results of various studies show that flexibility in MBSE still faces a number of challenges, especially related to the complexity of the model, the rigidity of modeling methods, and limitations in the iterative integration of changing needs.

In principle, MBSE has great potential to support change adaptation because the model structure allows traceability between system elements, from initial needs to final verification. With a well-defined model, changes in one element can be quickly analyzed for their impact on other elements, so that change decisions can be made in a more informed manner (Paredis et al., 2020). In addition, the model-based approach supports systematic documentation of changes, reducing the risk of losing critical information during the evolution of the project. However, in practice, managing changes in MBSE often becomes complicated as the size and complexity of the model increases. Madni and Sievers (2018) noted that large models developed in large-scale projects tend to be difficult to modify quickly, thus slowing down the response to changing needs or operational conditions.

One of the factors that limits the flexibility of MBSE is the rigidity of the modeling process itself. Many MBSE methods rely on highly formal and hierarchical stages, which while increasing accuracy, also reduce the team's agility in responding to changes (INCOSE, 2021). On the other hand, reliance on certain tools that are inflexible in supporting cross-domain or cross-system lifecycle model changes is also an obstacle. Experience across various digital projects shows that an imbalance between model depth and the need to adapt often leads project teams to choose to "bypass" formal modeling processes in the face of rapid change, thus detracting from the full benefits of the MBSE approach itself (Wang, Luo, & Zhang, 2020).

To increase flexibility, several innovative approaches within MBSE began to be developed. One such approach is the integration of agile system engineering principles into the MBSE framework. This concept encourages the iteration of the model in short cycles (sprint-based modeling), facilitates the development of a minimum viable model, and allows for quick feedback from stakeholders (Madni & Sievers, 2018). Thus, changes in needs can be responded to immediately with a structured but still rapid model update. In addition, the modular modeling approach, in which the system is divided into modular units that can be changed without disrupting the overall model, is also an effective strategy to increase the flexibility of MBSE (Friedenthal et al., 2022).

In addition to the methodological aspect, the human factor also plays an important role in determining the flexibility of MBSE. A work culture that supports change, openness to feedback, and the team's ability to adapt to project dynamics greatly affect the success of model adaptation. Schindel and Peterson (2020) emphasize the importance of the role of the curator model or model architect, which is the individual responsible for maintaining the consistency, completeness, and relevance of the model during the project. Without this role, changes that occur to the model are often poorly coordinated, which instead increases the risk of fragmentation and loss of system integrity.

The latest digital technologies also contribute to increased MBSE flexibility. The adoption of cloud-based modeling platforms, the use of collaborative modeling environments, and model integration with Git-based version control systems or continuous integration systems help teams to manage model changes more efficiently and in a controlled manner (INCOSE, 2021). In addition, the development of the Digital Twin concept, in which digital models evolve in line with the conditions of physical systems in real-time, allows for dynamic adaptation of the model to changes in the environment or actual operations (Wang et al., 2020).

Overall, the need for flexibility in MBSE is a reflection of the complex and ever-changing realities of digital projects. Without flexibility, MBSE risks becoming an administrative burden that hinders project agility. Therefore, innovation in the MBSE methodology, the adoption of adaptive supporting technologies, and the strengthening of a work culture that is responsive to change are the main keys to realizing MBSE that truly supports the success of digital infrastructure projects in the future. Further research is urgently needed to explore the optimal combination of rigorous modeling structures and the need for adaptability agility, so that MBSE can continue to evolve in line with the increasingly dynamic needs of the industry.

Comparison with Previous Studies

When compared to previous studies, this study strengthens the findings that the implementation of MBSE does have a significant positive impact, especially in improving the traceability of the need and accuracy of system verification (Friedenthal et al., 2022; Paredis et al., 2020). However, the study also found that aspects of change adaptation and multidisciplinary collaboration are still major challenges, which in some previous studies have not been discussed in detail. This shows that there is room for innovation to develop a more dynamic and collaborative MBSE methodology, in accordance with the characteristics of modern digital projects.

4. Conclusion

This study found that the application of Model-Based Systems Engineering (MBSE) in digital infrastructure projects faces major challenges in the form of need traceability, complexity management, multidisciplinary collaboration, and adaptation to change. MBSE has been proven to be able to increase the effectiveness of needs management and system integration, but it still needs to be strengthened in terms of flexibility and cross-disciplinary collaboration. This research answers its main objective by developing a methodological understanding of how MBSE can be adapted to address the complexity of modern digital projects through a robust, agile, and traceability-based approach. The limitation of this study lies in the limited scope of data taken from the case study and does not cover the implementation of MBSE in the broader industrial sector. Nonetheless, the study contributes theoretically by enriching the literature on the adaptation of MBSE to digital infrastructure and practically provides strategic recommendations for organizations in designing engineering systems that are more responsive to change. These findings are expected to be the basis for further research in developing a more dynamic, flexible, and collaborative MBSE framework in the ever-evolving era of digitalization.

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