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Challenges and Solutions in Managing the Modernization of Industrial Software

– Case Study of Sentinel and FLMS

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Challenges and Solutions in Managing the Modernization of Industrial Software

- Case Study of Sentinel and FLMS

As the digital landscape rapidly evolves, industrial software must be modernized to maintain competitiveness, operational efficiency, and security. The purpose of this thesis was to examine the challenges and solutions involved in modernizing Sentinel and Furnace Lining Monitoring System (FLMS) at a mining and metals refining technology company. Among the major barriers to modernization are legacy software constraints, cybersecurity risks and financial implications.

Through semi-structured interviews with key stakeholders directly involved in the Sentinel and FLMS modernization process, a qualitative case study approach was used. In order to analyze interview data, thematic analysis was used to categorize responses into technical, organizational, and financial categories. Additionally, the study examined best practices in software modernization, such as cloud adoption, microservices architecture and DevOps.

In order for modernization to be effective, a balanced approach that addresses both technical and organizational challenges is necessary. Integrating legacy systems requires re-architecting and re-platforming, while security risks can be mitigated by implementing cloud-native security frameworks.

Keywords:

industrial software modernization, cloud computing, digital transformation, DevOps, cybersecurity, AI-driven maintenance.

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Haasteet ja ratkaisut teollisten ohjelmistojen modernisoinnin hallinnassa

-Tutkimus Sentinelistä ja FLMS:stä

Digitaalisen maiseman nopeasti kehittyessä teollisia ohjelmistoja on modernisoitava kilpailukyvyn, toiminnan tehokkuuden ja turvallisuuden ylläpitämiseksi.

Opinnäytetyössä käytettiin laadullista tapaustutkimuksen lähestymistapaa puolistrukturoiduissa haastatteluissa keskeisten sidosryhmien kanssa, jotka ovat suoraan mukana Sentinel- ja FLMS-modernisointiprosessissa. Haastattelutietojen analysoimiseksi käytettiin temaattista analyysiä vastausten luokitteluun teknisiin, organisatorisiin ja taloudellisiin luokkiin. Lisäksi opinnäytetyössä tarkastellaan ohjelmistojen modernisoinnin parhaita käytäntöjä, kuten pilvikäyttöönottoa ja mikropalveluarkkitehtuuria.

Opinnäytetyö keskittyy teollisuuden ohjelmistojen modernisoinnin haasteisiin ja ratkaisuihin. Jotta modernisointi olisi tehokasta, tarvitaan tasapainoista lähestymistapaa, joka vastaa sekä teknisiin että organisatorisiin haasteisiin. Vanhojen järjestelmien integrointi vaatii uudelleenarkkitehtuuria ja alustan uudelleenjärjestelyä, kun taas tietoturvariskejä voidaan pienentää ottamalla käyttöön pilvipohjaisia tietoturvakehyksiä. Nämä väitteet pohjautuvat tutkimuksessa saatuun havaintoon ja analyysiin.

Asiasanat:

teollisuuden ohjelmistojen modernisointi, pilvilaskenta, digitaalinen muunnos, DevOps, kyberturvallisuus, tekoälyyn perustuva ylläpito

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List of abbreviations

FLMS	Furnace Lining Monitoring System
AI	Artificial Intelligence
ML	Machine Learning
IoT	Internet of Things
CI/CD	Continuous Integration/Continuous Deployment
NIST	National Institute of Standards and Technology
ISO	International Organization for Standardization
API	Application Programming Interface
AWS	Amazon Web Services
GDPR	General Data Protection Regulation
APA	American Psychological Association
UI/UX	User Interface / User Experience
3D	Three-Dimensional
WebGL	Web Graphics Library
PRINCE2	Projects IN Controlled Environments
TAM	Technology Acceptance Model

1 Introduction

Today, digital transformation plays a crucial role in improving operational efficiency, sustainability, and competitiveness. Increasingly, companies in industrial sectors are utilizing advanced digital technologies to optimize processes and improve decision-making. (Ramachandran, 2022.) Industrial software modernization poses several challenges, including legacy system integration, cybersecurity risks, cost implications, and workforce adaptation. (Min, Jeanne, and Suk, 2018.) In addition, a strategic roadmap is needed to ensure a seamless transition from traditional industrial processes to AI-driven, cloud-based solutions. (Seo, Yoo, and Lee, 2024.) It is possible for companies to experience disruptions in operations, data security vulnerabilities, and inefficiency in software adoption if they do not plan properly.

The purpose of this study is to examine the challenges and solutions for modernizing Metso's Sentinel and FLMS systems. Metso's Smelting Digital team has developed Sentinel and Furnace Lining Monitoring System (FLMS), two cutting-edge digital systems designed to enhance smelting operations. By integrating real-time monitoring, predictive analytics, and process automation, these systems improve efficiency, reduce downtime, and improve sustainability. (Metso, 2023.) As technology evolves, maintaining competitiveness necessitates continuous modernization of these digital tools.

This study, aims to:

- Identify and analyze key challenges encountered during modernization.
- Implement actionable solutions that ensure the successful transition to scalable, efficient, and future-ready digital platforms for Sentinel and FLMS.

The study adopts a qualitative research approach by conducting semi-structured interviews with key stakeholders involved in the modernization of Sentinel and FLMS. It examines technical, organizational, and financial challenges faced during the transition and explores best practices in industrial software modernization. To provide a comprehensive analysis, secondary sources such as academic literature and industry reports are also reviewed.

This research aims to provide practical insights for organizations undergoing digital transformation by addressing industrial software modernization challenges and solutions. In addition to strategic guidance, the research also covers microservices architecture, AI-driven analytics, and change management frameworks. (Ghobakhloo et al., 2024.) This study aims to contribute to a broader discourse on Industry 4.0 adoption, assisting companies to convert their digital platforms into scalable, efficient, and future-ready solutions. (European Commission, 2021.)

1.1 Company Background

Metso provides sustainable technologies, end-to-end solutions, and services to the aggregates, minerals processing, and metals refining industries. (Metso, 2024a.) Metso is headquartered in Helsinki, Finland, and operates in more than 50 countries. (Metso, 2024b.) Equipment, wear and spare parts, and services for aggregates production, mining operations, and metals refining are among Metso's extensive product and service portfolios. (Metso, 2024c.) As part of its commitment to sustainability, Metso focuses on resource efficiency, safety, and reducing environmental impact. (Metso, 2024d.) As a company, Metso values diversity and inclusion, fostering a culture that values different perspectives and backgrounds. (Metso, 2024e.) The company's strategic priorities include enhancing customer performance, driving growth through innovation, and leading in sustainability. (Metso, 2024f.) Metso integrates advanced digital solutions to optimize its customers' operations, contributing to a sustainable future. (Metso, 2024g.)

Metso's strong market position is a result of its dedication to continuous innovation and customer-centric solutions. (Metso, 2024c.) With artificial intelligence, automation, and digital twin solutions, the company enhances operational efficiency and predictability in industrial processes. (Metso, 2024g.)

Metso remains committed to sustainability, focusing on reducing carbon emissions, optimizing energy consumption, and promoting circular economy practices across its operations. (Metso, 2024d.) Furthermore, Metso collaborates actively with its customers to develop tailored solutions that improve productivity while minimizing environmental impact. (Metso, 2024f.) The company's diverse workforce fosters a culture of innovation that ensures adaptability to evolving industry trends and market demands. (Metso, 2024e.) It is through technological advancement and sustainability that Metso continues to strengthen its leadership in the industrial sector, paving the way for a more efficient and responsible future. (Metso, 2024a.)

1.2 Research Questions

This study explores key challenges for modernizing Sentinel and FLMS and proposes effective solutions. Research is guided by the following fundamental questions:

1. What are the challenges encountered during the modernization of Sentinel and FLMS at Metso?
2. What solutions and strategies can be implemented to overcome these challenges and ensure the successful transition of Sentinel and FLMS to modern, scalable, and efficient systems?

1.3 Research Objectives

The research aims to achieve two primary objectives:

1. To identify and analyze the challenges involved in the modernization of Sentinel and FLMS at Metso.
2. To propose actionable solutions and strategies for overcoming the identified challenges, ensuring the successful transition of these products to modern, scalable, and efficient systems.

2 Literature Review

This chapter aims to provide a framework for identifying future research areas and challenges in industrial software modernization, including key challenges, strategies, risks, and case studies.

2.1 Introduction to Software Modernization in Industrial Settings

In industrial settings, software modernization involves updating and transforming legacy software systems to meet current technological standards and business requirements. By re-architecting outdated applications, industrial operations will remain efficient and competitive in the evolving digital landscape by improving performance, security, and scalability. (Khan, 2023.)

According to Figure 1, software modernization encompasses several approaches, collectively referred to as the 7 R's of Legacy Application Modernization. Rebuilding involves transforming the entire system into a cloud-native environment, while rehosting involves moving legacy systems to new infrastructure without affecting their functionality. Refactoring, for example, optimizes backend components while maintaining the frontend, whereas replacing or retiring involves completely replacing outdated systems. Before selecting a modernization strategy, organizations should carefully assess their business needs, cost considerations, and long-term scalability goals. (Mistry, 2023.)

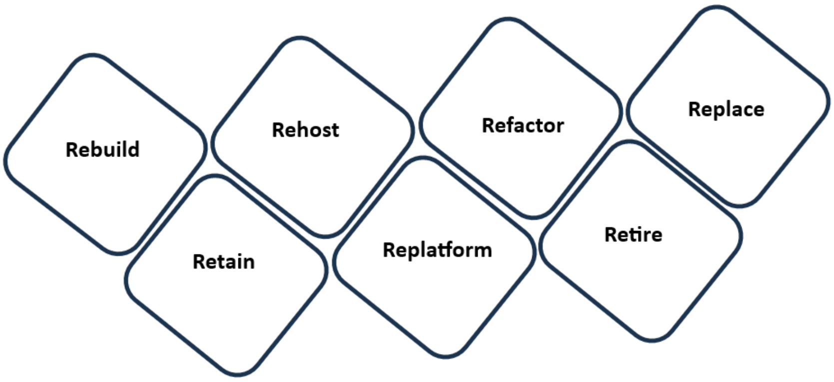

Figure 1. Software Modernization Process (Adapted from Mistry, 2023).

Industrial legacy systems, such as Sentinel and FLMS, often lack operational efficiency and innovation. Data silos and inefficient workflows may result from these systems' lack of integration capabilities with modern technologies. In addition, outdated software may not comply with current regulatory standards and pose significant security risks. In order to mitigate such challenges and to leverage technological advancements for improved operational outcomes, these systems must be modernized. (Khan, 2023.)

Achieving desired outcomes requires aligning software modernization efforts with business goals. By streamlining processes and reducing maintenance costs, modernization initiatives can enhance operational efficiency. The adoption of modern software solutions can facilitate better collaboration, real-time monitoring, and more effective resource allocation, leading to successful project execution. (Khan, 2023.)

2.2 Challenges in Industrial Software Modernization

The process of modernizing industrial software systems involves navigating a complex landscape of technical, organizational, and financial challenges. In order to update legacy systems like Sentinel and FLMS effectively, it is crucial to understand these obstacles.

Legacy System Constraints & Technical Debt

In today's technological environment, monolithic architectures present significant challenges for many industrial software platforms. Monolithic systems are inherently difficult to scale, maintain, and integrate with modern technologies such as artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT). Compared to monolithic architectures, microservices and cloud-native designs offer far greater flexibility, making updates and integrating new features much easier. These legacy systems accumulate technical debt over time due to inefficiencies in their code and architecture, making maintenance increasingly difficult and expensive. In order to improve system performance and reduce long-term operational costs, technical debt must be addressed. (Rafalski, 2024.)

Security, Compliance & Cyber Risks

In modern architectures, advanced cybersecurity measures, such as cloud security protocols and zero-trust frameworks, enhance protection against cyber threats. In spite of these precautions, modern systems can introduce new vulnerabilities, which makes comprehensively securing them more challenging. The migration of sensitive industrial data to cloud platforms complicates compliance with contemporary cybersecurity regulations, including ISO 27001 and the NIST cybersecurity framework. As a result, ensuring data integrity and security during the transition is more challenging. (Gierszal, 2024.)

Organizational & Workforce Adaptation

During software modernization efforts, resistance to change is a common challenge. Employees accustomed to legacy systems may be hesitant to adopt new technologies, causing workflow disruptions. Furthermore, the existing workforce must be upskilled to use AI, cloud computing, and data analytics tools integrated with modernized systems. Metso's modernization initiatives require meticulous project coordination and change management strategies in order to align with overarching business objectives and ensure seamless collaboration among engineering teams. A practical approach to software modernization is reflected in this approach. (Deore, 2022.)

Cost Implications & ROI

There are both direct and hidden costs associated with software modernization. The direct costs include licensing fees, development efforts, system migrations, and employee training programs. Hidden costs can manifest as productivity losses, data migration failures, and system downtimes during the transition period. These upfront investments are justified by the expected return on investment (ROI), which includes predictive maintenance capabilities, enhanced automation, and data-driven decision-making. Building a compelling business case for modernization initiatives requires quantifying these advantages. (Rinf Tech, n.d.)

In order to meet these challenges, a comprehensive approach that balances organizational change management and financial planning is necessary.

2.3 Modernization Strategies in Industrial Software Engineering

Maintaining competitiveness and leveraging technology advancements require modernizing legacy industrial software systems. These systems can be effectively updated using several strategies.

Software Reengineering Approaches

Figure 2 illustrates how legacy system modernization approaches vary in complexity, risk, and impact. There are three main levels of these approaches (Kovalenko, 2021).

- Technology-focused approaches (Encapsulation, Rehosting) – Encapsulating legacy components with APIs or migrating them to a new infrastructure (Rehosting) require minimal changes. There is the least complexity and risk associated with these approaches, but they also have the least impact on the functionality of the system.
- Architecture-focused approaches (Replatforming, Refactoring) – In order to improve performance and scalability, the architecture of the system needs to be modified. When replatforming, applications are moved to a new runtime environment with minimal changes, whereas when refactoring, code is restructured without affecting its external behavior. The complexity and impact of these approaches are balanced.
- Functionality-focused approaches (Re-architecting, Rebuilding) – Despite being complex and high-risk, these approaches are the most effective. By re-architecting the system, we are adapting modern technologies (e.g., cloud-native and microservices), whereas by rebuilding we are creating an entirely new system.

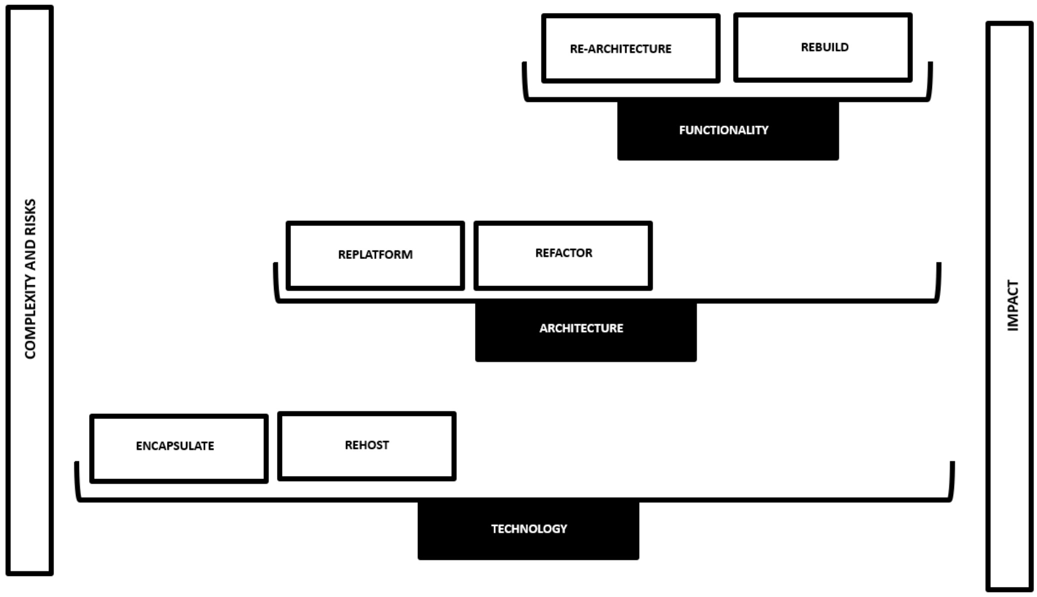

Figure 2. Core Legacy System Modernization Approaches (Adapted from Kovalenko, 2021).

Legacy software reengineering involves a variety of strategies, each with its own methodologies and outcomes:

- Encapsulation: Wrapping legacy components within APIs or services allows them to interact with modern systems without altering the original codebase. Through encapsulation, legacy applications can be integrated with new technologies. (vFunction, n.d.)
- Re-platforming: In re-platforming, applications are moved from legacy environments to modern cloud platforms such as AWS or Azure with minimal changes to their core architecture. In addition to enhancing scalability and performance, this strategy reduces operational costs. (Perry, 2020.)
- Re-architecting: Using this strategy, monolithic applications are transformed into microservices-based architectures. As a result of decomposing the application into smaller, independent services, organizations can improve scalability, maintainability, and facilitate the integration of advanced technologies such as AI, machine learning, and IoT. (Sommerville, n.d.)

- Full Replacement: In cases where existing systems are obsolete or unable to meet current business needs, new solutions must be developed from scratch. Despite its resource-intensive nature, this approach ensures that the new system meets modern standards and is future-proof. (vFunction, n.d.)

DevOps & Agile in Industrial Software Modernization

In industrial software modernization, modern software development methodologies, such as DevOps and Agile, play a crucial role. In addition to improving system performance, these approaches help organizations achieve faster release cycles, automate testing and deployment, and ensure continuous monitoring. (Maharao, 2022.)

Table 1 compares these methodologies, highlighting their individual advantages as well as their potential together for modernization. (Maharao, 2022.)

Table 1. Agile vs DevOps vs Combined Agile + DevOps (Adapted from Maharao, 2022).

Aspect	Agile	DevOps	Combined Agile + DevOps
Focus	Iterative development	Continuous integration/delivery	Iterative development and continuous delivery
Collaboration	High within development team	High between development & operations	High across all teams, including business
Time-to-Market	Faster with iterations	Faster with CI/CD pipelines	Very fast, ensuring constant product delivery
Quality	Continuous feedback on quality	Continuous testing and monitoring	High-quality delivery through feedback and automation

Flexibility	Highly flexible to changes	Focused on automation and stability	Flexible with efficient, automated delivery
Cultural Change	Promotes a flexible, team-oriented culture	Encourages collaboration between development and operations	Requires cultural transformation for both flexibility and collaboration

As shown in Table 1, Agile emphasizes iterative development and stakeholder collaboration, whereas DevOps emphasizes automation and operational stability. By integrating Agile and DevOps methodologies, industrial systems such as Sentinel and FLMS can benefit from continuous integration, automated testing, and streamlined deployments. (Maharao, 2022.)

For industrial software systems like Sentinel and FLMS to be successfully modernized, DevOps and Agile methodologies must be implemented:

- Faster Release Cycles: Continuous integration and continuous deployment (CI/CD) are key components of DevOps practices, which facilitate rapid and reliable release cycles. As a result of this agility, organizations are able to respond quickly to market changes and user feedback. (Digital.ai, n.d.)
- Automated Testing & Deployment: The automation of testing and deployment processes reduces human error, ensures consistency, and accelerates the delivery pipeline. Workflow automation facilitates the efficient management of complex industrial software systems. (Digital.ai, n.d.)
- Continuous Monitoring & Feedback Loops: Providing real-time insights into system performance and user experience, DevOps emphasizes ongoing monitoring and feedback loops. Continuous feedback is essential for proactive maintenance and iterative improvement. (Digital.ai, n.d.)

The agile methodologies, such as SCRUM and Kanban, complement DevOps by providing frameworks for managing development sprints, enhancing collaboration, and ensuring flexibility in project execution. By integrating CI/CD pipelines, updates to systems like Sentinel and FLMS are deployed seamlessly, maintaining system integrity and performance. (Digital.ai, n.d.)

AI-Driven Predictive Maintenance & Digital Twin Integration

In the modernization of industrial software, advanced technologies, including AI-driven predictive maintenance and digital twins, have become essential. The Digital Twin is a digital representation of a physical object, system, or process that can be used to simulate, analyze, and optimize real-world conditions and performance. Through this concept, organizations are able to monitor, predict, and optimize operations in real-time. Figure 3 shows a reference model for the Digital Twin. (Hananto et al., 2024.)

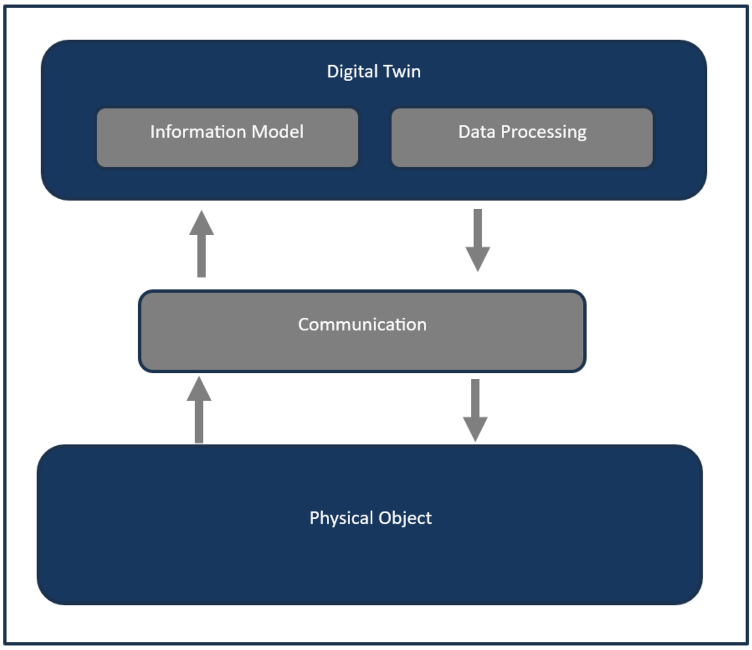

Figure 3. A reference model of Digital Twin (Adapted from Hananto et al., 2024).

Figure 3 illustrates three crucial elements in creating a Digital Twin. It is first necessary to simplify the complexity of a physical object by using an information model. The next step is to ensure the Digital Twin and real-world object can exchange data back and forth. The final component is a data processing unit that uses data from numerous sources to create a digital representation of the physical object. In order to construct a successful Digital Twin, these three components must work together. (Hananto et al., 2024.)

As legacy industrial systems are modernized, AI and IoT technologies play a crucial role:

- AI and IoT Integration: By integrating AI with IoT devices, industrial equipment can collect and analyze vast amounts of data. The integration facilitates advanced analytics and decision-making processes, thereby improving operational efficiency. (Bannon et al., 2024.)
- Predictive Maintenance Models: In AI-driven predictive maintenance models, data is analyzed to predict equipment failures before they occur. A proactive approach minimizes downtime, reduces maintenance costs, and extends the life of machinery. (Shanmugam, 2021.)
- Digital Twins: The term "digital twin" refers to a virtual replica of a physical system that simulates the conditions of the real world. A digital twin utilizes artificial intelligence to provide real-time monitoring, predictive analytics, and scenario testing, optimizing performance and facilitating informed decision-making. (Bannon et al., 2024.)

By incorporating these strategies, industrial software systems remain robust, adaptable, and capable of meeting today's operational demands.

2.4 Risks and Limitations of Modernization Strategies

In addition to offering significant benefits, modernization strategies such as cloud migration, automation, and AI-driven decision-making also pose new risks and challenges. In order to achieve a balanced approach to modernization, it is necessary to acknowledge these limitations and implement strategies to mitigate possible drawbacks. (Townsend, 2025.)

1. Network Dependency in Cloud Services

Industrial software systems can be scaled, flexible, and accessed remotely via the cloud, but they also become more dependent on the stability of the network. Cloud-based architectures require constant internet connectivity in contrast to on-premise solutions. (Townsend, 2025.)

Potential Issue: A manufacturing plant's cloud-dependent software could stop working if it loses its network connection. (Ghobakhloo et al., 2024.)

Migration Strategy: A hybrid cloud solution combines local servers for critical operations with cloud-based analytics to reduce the risk of network failures. (Buyya, Ilager and Arroba, 2023.)

2. Reduced Resilience in Automated Systems

In order to improve efficiency, automation replaces manual processes, but excessive reliance on automation can reduce system resilience. When unexpected problems arise, automated systems lack adaptive problem-solving capabilities. (Townsend, 2025.)

Example: Production may be halted unnecessarily if an automated quality control system flags too many false positives. (Shanmugam, 2021.)

Mitigation Strategy: By incorporating human oversight into critical decisions, automated systems remain flexible and adaptive. (Bannon et al., 2024.)

3. Outdated or Biased AI Decision-Making

In AI-driven industrial systems, historical data is used to predict failures and optimize performance. If the training data is outdated or biased, AI models may make incorrect decisions or fail to detect new anomalies. (Townsend, 2025.)

Example: It is possible for AI-powered predictive maintenance systems trained on old machine failure data to miss new failure patterns, resulting in unexpected breakdowns. (Min, Jeanne, and Suk, 2018.)

Mitigation Strategy: Using real-time operational data, AI models are constantly retrained to ensure accuracy and adaptability. (Rafalski, 2024.)

4. Cybersecurity Vulnerabilities in Cloud and AI Systems

When moving from on-premise to cloud-based solutions, modernization efforts can introduce cybersecurity risks. Cybercriminals can also exploit AI-driven predictive analytics systems. (Townsend, 2025.)

Example: It is possible to hack a cloud-hosted industrial control system, allowing unauthorized access to production settings. (Gierszal, 2024.)

Mitigation Strategy: Zero-trust architectures, AI-driven anomaly detection, and frequent cybersecurity audits reduce vulnerabilities. (Rose et al., 2020.)

5. Ethical and Compliance Challenges in AI Adoption

Artificial intelligence systems that analyze industrial processes may unintentionally introduce ethical issues related to worker surveillance, job displacement, or regulatory compliance. (Townsend, 2025.)

Example: AI-based performance monitoring may lead to unethical workforce tracking, raising privacy concerns. (European Commission, 2021.)

Mitigation Strategy: Trust and transparency can be maintained by following AI ethics guidelines and complying with GDPR and industry-specific regulations. (Aheleroff et al., 2022.)

2.5 Case Studies in Software Modernization

Examples of industrial software modernization efforts aligned with Metso's digital transformation initiatives are presented in the following case studies.

Case 1: Cloud Migration of an Industrial Process Monitoring System

By migrating to a cloud-based microservices architecture, a manufacturing company modernized its legacy process monitoring system. As part of the transition, the monolithic application was re-architected into discrete services deployed on platforms such as AWS and Azure. It has enhanced scalability, enhanced security measures, and enabled real-time analytics, thereby optimizing operational efficiency (Lomas, 2024).

Case 2: AI-Powered Predictive Maintenance in the Manufacturing Industry

In its process control software, a prominent manufacturing company implemented AI-driven predictive maintenance models. Through the integration of advanced analytics and machine learning algorithms, the company was able to reduce equipment downtime by 30%, decrease maintenance expenditures, and streamline production processes. It illustrates the potential of AI to enhance operational reliability and efficiency (Williams, 2024).

As these case studies demonstrate, adopting modern technologies in industrial settings can have tangible benefits, enhancing the digital capabilities of companies like Metso.

3 Research Plan

The purpose of this chapter is to describe the research methodology used to explore the challenges and solutions associated with the modernization of Sentinel and FLMS at Metso. This research utilizes semi-structured interviews with a small, focused group of professionals who are directly involved in the project because of the specific project environment and key stakeholders involved.

3.1 Research Design

Using a case study strategy, this study explores Sentinel & FLMS modernization using an exploratory qualitative approach. (Yin, 2014.) In order to gather expert perspectives, challenges, and strategies in the modernization process, semistructured interviews are conducted with a limited but highly relevant pool of participants.

- Research Approach: Qualitative (Exploratory Case Study)
- Data Collection Method: Semi-structured interviews
- Target Participants: Key project stakeholders at Metso
- Objective: To explore challenges, best practices, and modernization strategies in Sentinel & FLMS

3.2 Research Methodology

The author selected semi-structured interviews to ensure a structured yet flexible discussion that allows respondents to share their experiences while ensuring alignment with research goals. (Kallio et al., 2016.)

- Interview Type: Semi-structured, one-on-one interviews
- Mode: In-person or virtual (via Teams) depending on participant availability

- Duration: 30–45 minutes per interview
- Recording & Transcription: With participant consent, interviews will be recorded and transcribed for analysis

The study will collect data from individuals involved directly in Sentinel and FLMS modernization projects. The project participants are selected based on their role, experience, and decision-making capacity.

3.3 Conceptual Framework

Using the research questions and objectives of this study, a conceptual framework was developed as shown in Figure 4.

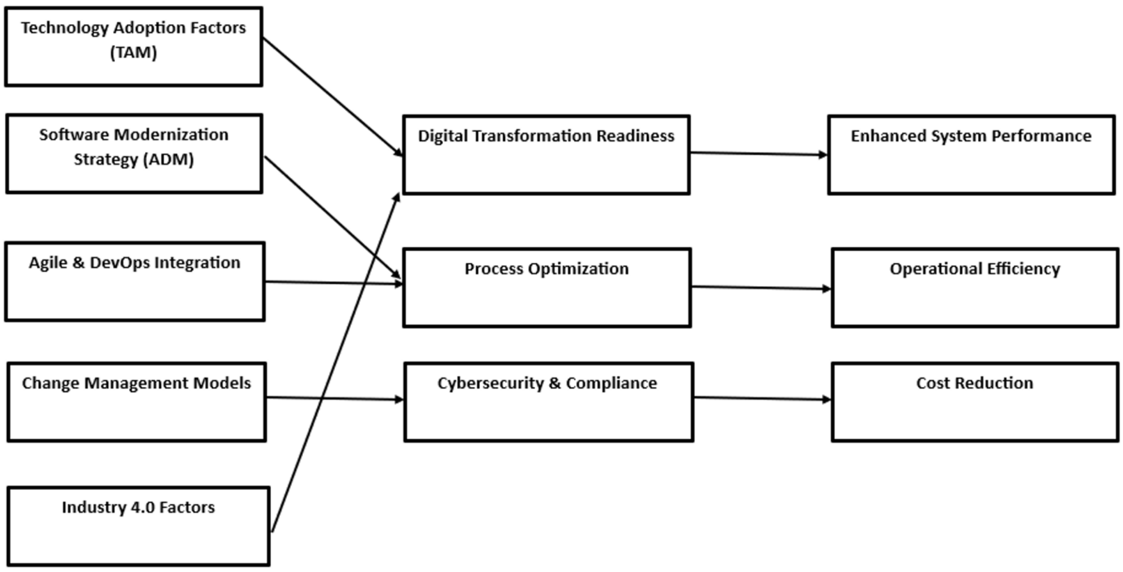

Figure 4. Conceptual Framework (created by the author).

As illustrated in Figure 4, the modernization process is directly influenced by technology adoption factors, software modernization strategies, Agile & DevOps methodologies, change management approaches, and Industry 4.0 enablers. These elements drive the transition from legacy systems to modernized, scalable, and AI-integrated industrial software.

However, the effectiveness of these modernization initiatives depends on key transformation mechanisms, such as digital transformation readiness, process optimization, and cybersecurity & compliance. In addition to improving Metso's operational efficiency and mitigating the risks associated with upgrading legacy systems, these variables ensure that the modernization process is strategically aligned with Metso's operational needs.

Modernization efforts are ultimately measured by variables, which represent expected outcomes. Enhancing system performance, improving operational efficiency, and reducing costs are some of these benefits. Based on the relationship between independent, mediating, and dependent variables, Metso's digital transformation strategy can be evaluated in terms of innovation, sustainability, and long-term competitive advantage.

In order to ensure a structured and data-driven approach to industrial software transformation, this conceptual framework analyzes the interaction between technological, organizational, and process factors.

3.4 Participants & Sampling Strategy

The participants were selected using purposive sampling because they represent key decisionmakers and contributors to the modernization project for Sentinel & FLMS. It ensures that individuals who are directly involved in the planning, implementation, and usability of the strategy will provide insights. (Palinkas et al., 2013.)

A summary of the selected participants, their roles, and their contributions to modernization is provided in Table 2. By including all key decision-makers and implementers involved in the modernization process, this small but highly relevant sample provides comprehensive insights into the modernization process.

Table 2. Participants & Sampling Strategy.

Participant Role	Number	Justification for Selection
Project Manager	1	Manages the overall modernization strategy and aligns it with business goals.
Project Owners	2	Manage Sentinel & FLMS feature updates and modernization priorities.
Developers	2	Ensure scalability and performance by implementing technical aspects of the modernization process, including software architecture, cloud integration, and system optimization.
UI/UX Designer	1	Ensures Sentinel and FLMS are user-friendly and conform to usability standards.
Manager (Sponsor)	1	Provides executive oversight, resource allocation, and strategic alignment.
Project Coordinator (Author's Role)	1	Coordinates project execution, communication, and stakeholder alignment.

3.5 Interview Design & Questions

A semi-structured interview design allows for a structured discussion while allowing participants to elaborate on key themes. (Kallio et al., 2016.) In order to explore each stakeholder's specific role in modernizing Sentinel & FLMS, questions were tailored to each group.

Key focus areas of the interviews were:

- Project Management & Strategy – Analyzing how modernization aligns with business goals, risk mitigation, budgeting, and project execution.
- Feature Prioritization & Technology Decisions – Analyzing how product owners and developers balance business needs with technical feasibility, user requirements, and long-term scalability.

- Software Architecture & Integration – Analyzing cloud adoption, microservices, API strategies, and handling technical debt.
- User Experience & Adoption – Incorporating user feedback, addressing usability concerns, and addressing design challenges.
- Business Justification & Stakeholder Engagement – Taking a closer look at leadership decisions, investment rationalization, and cross-functional collaboration.

Stakeholder groups were asked role-specific questions aligned with their expertise. Detailed interview questions can be found in Appendix 1.

3.6 Data Analysis Method

Thematic analysis is used to analyze interview data because it is suitable for identifying patterns within qualitative data. Using thematic coding, data can be categorized according to recurring patterns or concepts, a key part of this process. The interview transcripts are reviewed in detail to identify these themes, allowing for a deeper understanding of the challenges and strategies associated with the modernization of Sentinel & FLMS. (Braun & Clarke, 2021.)

In order to provide comprehensive insights into the modernization process, thematic analysis will focus on identifying key themes that emerge from the data. (Braun & Clarke, 2021.)

3.7 Ethical Considerations

A strict adherence to ethical research guidelines will ensure participant confidentiality, informed consent, and the protection of data. (APA, 2020.)

- Informed Consent: As part of ethical research compliance, participants will be verbally informed about the study's purpose, their voluntary participation, and their right to withdraw at any time. (APA, 2020.)

- Confidentiality: Researchers will not disclose any personal information in their final research reports. (APA, 2020.)
- Data Security: Interview recordings and transcripts will be securely stored and accessible only to researchers. (APA, 2020.)

4 Findings and Discussion

This chapter presents the findings of semistructured interviews conducted with key Metso stakeholders involved in the modernization of Sentinel & FLMS. During modernization, the primary objective was to understand the challenges faced and the strategies implemented to overcome them. Interviews were conducted with the key stakeholders directly involved in this project. There are two main sections to the findings:

1. The key challenges in modernization, which are faced by different roles in the process.
2. A list of solutions and best practices detailing how these challenges were addressed by the team.

A discussion section will provide a broader theoretical context for the findings by connecting the findings to relevant academic literature.

4.1 Challenges in Modernizing Sentinel & FLMS

Several challenges have been identified during Metso's modernization of Sentinel and FLMS, including cross-functional collaboration, technical debt, and legacy systems, risk management, and user feedback. A deeper understanding of these challenges is provided in this section, which integrates insights from secondary sources.

1. Cross-Functional Collaboration

Complex projects like system modernization require effective cross-functional collaboration. The Project Manager and Product Owners at Metso highlighted the need for cross-disciplinary collaboration as a primary challenge. In this project, stakeholders from different domains are involved, such as software developers, designers, metallurgists, and business owners. Getting the right people to work together at the same time, from different departments, with different expectations, is the most difficult aspect, according to the Project

Manager. To ensure alignment among teams with distinct priorities and working methods, effective communication was crucial. The Product Owners also noted that balancing business needs with technical feasibility was complicated.

In the author's role as a Project Coordinator, facilitating smooth team communication was a key responsibility. To prevent misalignment, this required coordinating meetings, making sure the right stakeholders were involved at the right time, and clarifying the scope of discussions. It was difficult to overcome departmental silos, in which teams focused more on their own immediate goals than on the success of the entire project.

One global manufacturer of cranes and lifting solutions, Palfinger, had similar challenges in managing and collaborating projects. In order to address these issues, Palfinger implemented Smartsheet, a workflow software designed to improve collaboration between departments and locations. Using Smartsheet's intuitive interface and automation features, seamless communication was made possible, reducing the need for emails and meetings. As a result of this change, both internal and external stakeholders were able to access and share project data with ease, improving transparency and streamlining processes. In a year, Palfinger has grown from 50 to 350 projects managed through Smartsheet, including the construction of a new plant in Serbia and the transfer of product assembly across continents. (Benady, 2025.)

In cross-functional collaborations, challenges often arise due to culture, communication styles, and objectives that differ between departments. The integration of project management tools, which provide real-time updates, centralized data repositories, and customizable workflows, helps mitigate these issues. The use of these tools not only helps to bridge communication gaps, but also fosters a culture of accountability and transparency.

2. Technical Debt and Legacy Systems

The Sponsor and Software Developer both commented on the challenges of technical debt in existing systems, which influenced the decision to upgrade them. The Sponsor emphasized that the FLMS platform was outdated and becoming increasingly difficult to upgrade, making the system no longer deliverable. Additionally, the software developer explained that even though the 3D visualization components were being modernized, limitations in the legacy system impacted the project scope. Many interviewees discussed the importance of moving from legacy architecture to a more scalable solution.

According to the author (Project Coordinator), tracking and documenting technical debt was crucial to ensuring the effectiveness of modernization efforts. In order to meet the project’s timeline, it was important to prioritize which technical debts should be addressed first.

There are many factors that contribute to technical debt, including business pressures leading to rushed development, knowledge gaps among members of the team, and an inadequate understanding of best practices. As this debt accumulates, maintenance costs increase, system efficiency decreases, and innovation is hindered. Updates or integrations of new functionalities are further complicated by legacy code's complexity, often compounded by outdated or lacking documentation. (Nielsen, Madsen, & Lungu, 2020.)

A strategic approach is required to address technical debt. Audits must be conducted comprehensively by organizations to identify and prioritize debt-laden areas. As part of this process, code refactoring, documentation updates, and the adoption of modern development frameworks are crucial. Furthermore, fostering a culture that emphasizes code quality, continuous learning, and best practices can prevent technical debt from accruing. (Nielsen, Madsen, & Lungu, 2020.)

3. Risk Management

Risk management was another key challenge identified during the interviews. Project Managers discussed the importance of identifying risks early in the process, as well as evaluating them continually. "Whenever you see a risk, you should react immediately, otherwise it will escalate to a bigger problem." This proactive approach to risk management emphasizes the importance of regular reviews and adjustments throughout the project's lifecycle. In addition, performance issues and the integration of new technologies were discussed as potential risks.

There are several risks associated with legacy system modernization:

- Data Migration and Integration Risks: It is common for legacy systems to store vast amounts of critical data in outdated formats. It is challenging to migrate this data to modern platforms without compromising integrity. Due to the high risk of data loss, inconsistencies, and integration issues, meticulous planning and execution are necessary. (Shukla, 2025.)
- Security and Compliance Risks: Using outdated systems may make them vulnerable to security breaches since they don't comply with current standards. Compliance with regulatory standards and protecting sensitive information depend on addressing these vulnerabilities. (Shukla, 2025.)
- Performance and Scalability Issues: In today's businesses, legacy applications may struggle to meet performance and scalability requirements. For these systems to be upgraded, bottlenecks must be identified and addressed to enhance efficiency. (Shukla, 2025.)

To mitigate these risks, comprehensive data audits, secure backups, and comprehensive testing are all key components of a robust data management strategy. As part of the risk management process, it is also essential to adopt modern security protocols, to ensure compliance with regulatory guidelines, and to optimize system performance. (Shukla, 2025.)

4. User Feedback and Adoption

Another challenge of the user adoption was identified by the UI/UX Designer and Product Owners. Even after making significant progress in modernization, the challenge remained in ensuring that end users could effectively use the new tools. In addition to being intuitive, the UI/UX Designer stressed the importance of an easy-to-navigate user interface. However, the Product Owners also noted that there was no formal user feedback mechanism in place, making it hard to anticipate user challenges.

Many organizations face resistance from users who are accustomed to legacy systems. It is common for users to resist change, often due to familiarity with existing systems and apprehension towards new technologies. User engagement early in the design process is essential to overcoming this problem. By incorporating their feedback, intuitive, and user-friendly interfaces can be created. Further facilitation of smooth transitions is provided by comprehensive training programs and continuous support. (Benady, 2025.)

In Palfinger's case, Smartsheet improved project management and increased user engagement. Users were empowered by the platform's user-friendly design and ability to customize workflows, which led to increased adoption and reduced reliance on traditional communication methods. The case illustrates the importance of choosing tools that are aligned with users' needs and capabilities. (Benady, 2025.)

Metso's challenges in modernizing Sentinel and FLMS reflect broader industry trends. To successfully resolve these challenges, cross-functional collaboration must be fostered, technical debt must be strategically managed, risk management practices must be implemented proactive, and user feedback must be prioritized. In order to navigate the complexities of system modernization more effectively, organizations should integrate insights from both primary and secondary sources.

4.2 Solutions and Best Practices for Successful Modernization

In order to address the challenges faced in the modernization of Sentinel & FLMS at Metso, best practices and strategic solutions had to be adopted. Several approaches were highlighted as contributing to the project's success in interviews with key stakeholders. These approaches align with established industry practices. Throughout this section, insights from both primary data sources (interviews) and secondary sources (academic and industry literature) are integrated to provide a well-rounded perspective on solutions and best practices.

1. Clear Project Vision and Stakeholder Communication

The interviews consistently emphasized the importance of maintaining a clear project vision and ensuring transparent communication. Managing cross-functional teams requires involving the right people from the beginning, according to the Project Manager. "Starting meetings by explaining why a person is invited and how they contribute to the project ensures active participation." This approach, based on open communication, helped establish a shared understanding of the project goals.

The Kotter Change Model (2012) suggests that successful transformations require an effective communication of the vision throughout the organization. An employee's engagement in a modernization initiative is more likely when they understand its broader purpose. Researchers have found that ambiguity in communication leads to project failure. (Taylor, 2018.)

The engagement of stakeholders has been a critical success factor in similar digital transformation projects. In a study by Ghobakhloo et al. (2024), active participation from business leaders, engineers, and IT specialists significantly improved project outcomes. By establishing a structured communication framework, companies were able to reduce resistance to change and align their projects more effectively. (Min, Jeanne, and Suk, 2018.)

A structured communication strategy was followed during the project of modernizing Sentinel & FLMS, involving cross-functional teams and ensuring alignment between business and technical stakeholders. By taking this approach, stakeholders were better aligned with modernization efforts and they were more committed.

2. Strategic Prioritization of Features

The Product Owners explained that the modernization of Sentinel & FLMS was motivated by the need to prioritize critical features while still maintaining the functionality of the old software. According to the UX/UI Designer, the main requirement was to ensure that the new software worked as well as the old one, so that new and existing clients could find it easy to use. This led to balancing existing feature functionality with new enhancements as a basis for prioritization. By taking this pragmatic approach, the project could provide immediate business value while also laying the groundwork for future enhancements.

According to industry research, prioritizing features is vital for software modernization projects. In a study on software redevelopment projects, Sommerville (2016) found that "modernization efforts should aim to provide incremental improvements while maintaining backward compatibility." Bannon et al. (2024) found that users are more likely to adopt new features if core functionalities are prioritized before new features are introduced.

There are a number of frameworks that have been successfully used in modernization projects for prioritizing tasks:

- MoSCoW Method (Must-have, Should-have, Could-have, Won't-have): In this method, features are classified based on their necessity and urgency. (Clegg & Barker, 1994.)
- Kano Model: Using this model, modernization can be differentiated between basic, performance, and excitement features in order to ensure that functions and user experiences are met at the same time. (Kano et al., 1984.)

As in these frameworks, this project of modernizing Sentinel & FLMS retained essential functionality while introducing enhancements over time.

3. Agile Methodology and Hybrid Approach

Agile methodologies played a key role in the project's success. The Project Manager, however, pointed out that while Agile provides flexibility, a hybrid model is actually used in practice. "We adapted the planning as we went, allowing us to step out of the pre-defined goals when new opportunities or challenges came up," said the Project Manager. As a result of this approach, the team was able to pivot quickly when new requirements were identified during development, ensuring that the software could adapt to changing business needs in the future.

According to research, Agile methodologies improve software modernization efforts by:

- Enhancing adaptability: The agile method enables teams to respond efficiently to emerging challenges. (Beck et al., 2001.)
- Improving collaboration: Developers must maintain constant feedback loops with users and stakeholders in order to maximize the success of their projects. (Fowler & Highsmith, 2001.)

Despite the benefits of Agile, hybrid projects are needed for some modernization projects. According to Shanmugam (2021), enterprise software development is better managed and cost controlled when Agile is combined with structured methodologies (such as PRINCE2).

The project followed a similar model, maintaining Agile sprints while clearly defining strategic milestones. Long-term project goals were balanced with short-term adaptability.

4. Leveraging New Technologies

Among the key drivers of the modernization project was the need to integrate new technologies, such as cloud computing, IoT, and Industry 4.0 standards, into the system. WebGL (Web Graphics Library) is a JavaScript API that allows interactive 3D graphics to be rendered within web browsers without plugins. Users can visualize and render 3D directly in the browser in real time, improving performance and accessibility. (Khronos Group, 2024.) According to the Full Stack Developer, WebGL allowed for smoother performance for 3D rendering and visualization. The Project Manager also stressed the importance of adopting new standards and libraries, especially for outdated legacy systems. As a result of these technological updates, the project was streamlined and made more future-proof and scalable.

Providing scalability, flexibility, and cost efficiency, cloud computing is a key enabler of digital transformation. Ghobakhloo et al. (2024) highlight that converting legacy on-premises systems to cloud-based solutions improves system reliability and reduces maintenance costs.

For 3D rendering, Metso's Software Developer recommended using WebGL. With WebGL, real-time visualization is possible within a web browser, improving performance and accessibility. In industrial applications, advanced visualization techniques can significantly enhance operational efficiency (Bannon et al., 2024) based on research on digital twin technologies.

Sentinel & FLMS were designed to be a future-ready system by leveraging these new technologies.

5. Risk Mitigation Strategies

In order to manage risk during software modernization, several techniques have been suggested:

- Prototyping: By developing small-scale prototypes, potential risks can be identified early. (Min, Jeanne, and Suk, 2018.)
- Incremental deployment: With phased rollouts, teams can monitor performance and resolve issues in a systematic manner. (Mullapudi, 2019.)
- Regular audits: Performing regular security and performance audits ensures system stability and compliance. (Rafalski, 2024.)

6. Focus on Long-Term Scalability

A key objective of the project was long-term scalability, according to the Product Owners and Project Manager. Sentinel 4.0 aims to provide a more flexible and scalable solution through re-architecting the system and integrating modern frameworks. Future integration with various types of equipment and systems was emphasized by the Product Owners.

In order to be scalable, systems need to be capable of handling increased workloads and additions to functionality over time. In studies on scalable software architectures (Sommerville, 2016), modular and microservice-based architectures have been found to enhance the longevity of systems.

Metso's modernization approach ensured long-term adaptability by incorporating the following elements (Sommerville, 2016):

- Standardized APIs: Providing easier integration with other industrial software.
- Future-proofing the architecture: Making sure that future AI-driven enhancements can be accommodated.

A modular, flexible software design strategy supports broader industry trends, in which companies seek to maintain innovation over the long term by building modular, flexible software applications. (Sommerville, 2016.)

In terms of software redevelopment, Metso's modernization of Sentinel & FLMS is an example of best practices. In order to overcome the complexities of modernization, Metso adopted a structured communication approach, prioritized features strategically, deployed Agile methodologies, and integrated new technologies.

Further, industry research indicates that these strategies are consistent with those used in similar projects around the world. In order to overcome modernization challenges, addressing risks early, ensuring long-term scalability, and maintaining a hybrid Agile approach have been crucial. (Sommerville, 2016.)

Insights from this study provide a valuable benchmark for future modernization projects, demonstrating that innovative technology, structured planning, and agile adaptability can result in success.

4.3 Data Analysis and Discussion

A series of challenges and solutions were identified during Metso's modernization of Sentinel & FLMS. These challenges and solutions align with broader themes in digital transformation and software modernization. The purpose of this section is to critically analyze the findings from sections 4.1 Challenges in Modernization and 4.2 Solutions and Best Practices, integrating theoretical perspectives and industry research to provide a comprehensive understanding of how the project functions.

1. Cross-Functional Collaboration and Change Management

A major challenge of the modernization process was coordinating cross-functional teams, particularly software developers and metallurgists with business stakeholders and after-sales teams. Managing diverse stakeholders with different priorities and working styles is challenging, according to the Project Manager and Product Owner.

There is a strong alignment between this challenge and established organizational change management theories. According to Kotter's 8-Step Change Model (2012), large-scale transformations require:

- A clear vision for change (defining the modernization goals) is necessary.
- Aligning stakeholders through effective communication.
- Building momentum requires short-term wins.

The Project Coordinator (author's role) was crucial to ensuring that communication channels remained open and stakeholders remained aligned in the Sentinel & FLMS project. Despite these efforts, resistance to change was evident, especially among teams who had been using legacy systems for many years. To manage such resistance, Lewin's Change Management Model (1947) suggests an unfreezing phase, in which stakeholders are educated about the necessity of change. Similar challenges have been faced by other organizations undergoing digital transformation.

Key Takeaways:

- In order to engage stakeholders more effectively at Metso, multi-departmental workshops should be held more often.
- Digital collaboration tools should be used more extensively to improve transparency and real-time communication.
- It is essential to formalize change management strategies in order to address resistance before modernization efforts are undertaken.

2. Technical Debt and Modernization Strategies

Sentinel & FLMS modernization was largely driven by the need to eliminate technical debt. As the Sponsor and Software Developer stressed, the legacy system was becoming increasingly difficult to maintain, requiring urgent action to prevent further deterioration.

As defined by Beal (2024), technical debt refers to short-term software development decisions which result in long-term inefficiency. According to research, organizations often accumulate technical debt due to (Beal, 2024):

- Business pressures lead to rushed development cycles.
- An aging software architecture that is difficult to integrate.
- The lack of documentation makes future modifications difficult.

A dilemma often faced by modernization projects is whether to refactor or redevelop. (Sommerville, 2016.)

Technical debt can be addressed using a variety of strategies Beal (2024):

- Incremental modernization - Updating systems gradually rather than rewriting them from scratch.
- Refactoring legacy code to improve efficiency without changing the behavior of the system.
- Removing obsolete dependencies and replacing them with modern frameworks.

Based on these recommendations, Metso followed a similar approach. Instead of rewriting the system from scratch, the team transitioned to WebGL for 3D rendering.

Key Takeaways:

- To minimize disruption, modernization projects should balance refactoring and new development.
- A technical debt management process is an ongoing one, requiring regular code reviews as well as documentation.
- Maintaining a modern development framework from the beginning prevents excessive accumulation of technical debt.

3. Risk Management in Software Modernization

In order to ensure project success, risk management was emphasized as a critical factor. The Project Manager stressed the importance of identifying and mitigating risks early, especially regarding data migration, security, and scalability.

It has been found that companies with organized risk assessment frameworks have a 40% higher chance of completing modernization projects on time. (Rafalski, 2024.) In Siemens' digital transformation initiatives, for example, testing and rollback strategies were rigorously implemented to prevent critical failures. (Ghobakhloo et al., 2024.)

Key Takeaways:

- Metso should formalize its risk management frameworks and incorporate industry best practices into them.
- Regular system audits should be conducted to address security vulnerabilities in a proactive manner.
- The development pipeline should include automated testing and validation tools.

4. User Feedback and Adoption Challenges

In the modernization process, user adoption was a major challenge. In spite of the technical improvements, users were hesitant to transition to the new platform, according to the UI/UX designer and product owners.

The following are the factors that contribute to user adoption, according to Davis' Technology Acceptance Model (TAM) (1989):

- Whether users perceive the system as useful or not.
- How intuitive and easy-to-use it is.

Metso should consider the following to improve adoption rates:

- In order to identify pain points, usability testing should be conducted before deployment.
- Rather than introducing abrupt system changes, phased training programs should be introduced.
- Supporting continuous usability refinement through ongoing support and feedback mechanisms.

Key Takeaways:

- Users should be consulted during the design process - Systems should be designed based on user feedback.
- In order to facilitate smoother transitions, formalized training programs should be implemented.
- New systems can be made more intuitive by allowing users to customize workflows.

5 Conclusions And Recommendations

This thesis aimed to critically analyze the challenges and propose effective solutions for modernizing industrial software systems, focusing on Metso's FLMS and Sentinel systems. This study on Metso's modernization of Sentinel and FLMS has shed light on the challenges, best practices, and potential improvements in industrial software modernization. It is clear from the findings that cross-functional collaboration, technical debt management, risk mitigation, and user adoption are critical success factors in modernization.

Research confirms that digital twins, AI-driven predictive maintenance, and IoT integration enhance industrial efficiency and decision-making. In order to avoid excessive technical debt, organizations must balance refactoring legacy systems with adopting new frameworks during the modernization of Sentinel and FLMS. Modernization projects are also more likely to succeed when structured risk management frameworks are in place and proactive user engagement is implemented.

Metso's approach to digital transformation is largely aligned with best practices. The study, however, identifies areas for improvement, including stakeholder engagement, change management, and structured risk assessment. It is essential to improve collaboration tools, formalize risk assessment strategies, and implement user-centric design principles in future digital transformation initiatives.

Based on the collected data, several key challenges emerged as a result of the modernization of Sentinel & FLMS:

- The challenge of overcoming communication barriers across teams in cross-functional collaboration.
- Determining whether to refactor or completely redevelop based on technical debt and legacy system constraints.
- Achieving data security, scalability, and risk management complexity.

- Ensure smooth transition of users to the new system by removing any hurdles to adoption.

As a result of the analysis, Metso's approach aligned with best practices in digital transformation, including incremental modernization, structured risk management, and hybrid Agile methodologies. In addition, stakeholder communication, proactive risk mitigation, and user engagement strategies can be improved.

Recommendations

Following the findings of the study, the following recommendations are proposed:

- Plan and implement cross-functional collaboration strategies.
- Improve communication by using digital project management tools.
- Manage technical debt by balancing incremental modernization with refactoring.
- Formalize software modernization risk assessment frameworks.
- Ensure regular security audits are conducted and automated testing tools are implemented.
- Utilize phased training programs and usability testing to enhance user adoption.
- Develop customizable workflows to make the system easier to use.
- Optimize operational efficiency with AI-driven predictive maintenance.
- Optimize real-time systems using digital twin models.
- Adopt Industry 4.0 innovations to align modernization efforts.

6 Limitations

The scope of this study is limited to Metso's modernization project, making some findings industry-specific. It is possible that case studies and literature do not adequately capture the implementation complexities that occur in real time. Furthermore, as digital twin technology and AI evolve rapidly, some conclusions may become obsolete. Moreover, no quantitative user experience metrics are provided in the study, so further behavioral research is needed to understand how users adopt new technologies.

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Interview Questions

Questions for the Project Manager (Focus: High-level project execution, business alignment, and risk management)

1. What are the biggest challenges you have faced in managing the Sentinel & FLMS modernization?
2. How does the modernization project align with Metso's business objectives and digital transformation strategy?
3. How do you ensure that the modernization process stays within budget and timeline constraints?
4. What risk mitigation strategies have you implemented in this project?
5. How have Agile and DevOps methodologies influenced project execution?
6. What lessons have you learned from previous software modernization projects?

Questions for Product Owners (2 Participants) (Focus: Feature prioritization, technology decisions, user needs)

1. How do you prioritize features and improvements in the modernization roadmap?
2. What challenges have you encountered in defining requirements for the new system?
3. How do you balance business needs with technical feasibility?
4. What are the key differences between the legacy system and the modernized version?
5. How do you incorporate user feedback into system improvements?
6. What long-term vision do you have for Sentinel & FLMS?

Questions for Full Stack Developer (Focus: Software architecture, migration strategies, cloud integration, DevOps, APIs)

1. What are the biggest technical challenges in modernizing Sentinel & FLMS?

2. How did you handle technical debt and refactoring of backend/frontend systems?
3. Which cloud technologies (AWS, Azure, GCP) have been most beneficial in the modernization process?
4. What role do microservices and APIs play in enabling better scalability and integration?
5. How do DevOps practices (CI/CD, automated testing) improve the modernization workflow?
6. What security concerns did you consider when modernizing backend/frontend components?

Questions for 3D Scientist (Focus: 3D visualization, AI-driven modeling, GPU acceleration, rendering techniques)

1. What are the biggest challenges in integrating 3D modeling into the modernized Sentinel & FLMS?
2. How does AI/ML enhance real-time 3D simulations in industrial software?
3. Which rendering techniques (ray tracing, real-time shading, etc.) are most effective for visualization?
4. What role does GPU acceleration (CUDA, Vulkan, DirectX) play in improving system performance?
5. How do you optimize large-scale 3D models for real-time processing and interaction?
6. What are the key technical differences between legacy and modern 3D visualization approaches?

Questions for UI/UX Designer (Focus: User experience, design challenges, usability concerns)

1. What were the main UI/UX challenges in modernizing Sentinel & FLMS?
2. How did you ensure the new system remains user-friendly and intuitive?
3. What steps were taken to test and validate the new interface?

4. How do you balance design consistency with new technological advancements?
5. What kind of user training materials were needed for the transition?

Questions for Sponsor (Line Manager) (Focus: High-level business strategy, resource allocation, leadership decisions)

1. What are the key business drivers behind the modernization of Sentinel & FLMS?
2. How do you justify the investment in software modernization to senior management?
3. How does this project fit within Metso's long-term digital strategy?
4. What role do Industry 4.0 technologies (AI, IoT, Cloud) play in this modernization?
5. How do you ensure cross-team collaboration in this project?

Questions for Project Coordinator (Since the author is also part of the team, the author can document their own reflections as part of the research)

1. What role does the author play in facilitating communication between stakeholders?

2. What challenges has the author faced in coordinating project timelines and deliverables?

3. How does the author ensure that the modernization process is aligned across different teams?

4. What lessons has the author learned from their experience managing this project?