Politecnico di Torino

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Master's Degree in Engineering and Management

Thesis Title: "The Influence of PMIS-IT System Integration on Project Efficiency and Collaboration."

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ABSTRACT

This thesis explores project management information system (PMIS) when integrated into other available software tools and information technology (IT) systems to enhance overall effectiveness in project management, communication, and data flow, particularly in complex and multi-stakeholder projects. A systematic literature review (SLR) was carried out for the present study using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to ensure completeness and a structured approach in analysis. The integration categories that are emphasized include collaboration and communication platforms, integrated analytical and decision-making support tools, and integrated resource and process management systems. The integration of these features can improve project coordination and interoperability among remote or geographically dispersed teams through real-time data sharing. This reduces data re-entry, allows for informed decisions based on insights from data, hence giving the teams options that lead to optimized resource allocation and risk mitigation. The findings show that PMIS integrations organize data and eliminate information bottlenecks, allowing increased transparency for project teams. Even with such advantages, a couple of those limiting factors have been indicated in the present literature, which apparently fails to engage with the studies concerning the longer-term impact of PMIS integration. Secondly, even with the new functionalities introduced by the smart project management information system (SPMIS) solutions (van Besouw & Bond-Barnard, 2021), very little integration of AI and ML is found, which can elevate the capabilities of PMIS.

The integration of artificial intelligence (AI) and machine learning (ML) with PMIS opens up new possibilities for predictive analytics and automation capabilities. Such developments have the potential to aid project managers in determining various risks, optimizing resource distribution, and making readjustments with a view of meeting very dynamic project demands and continuous change. This study gives industry practitioners practical insights on how to leverage integrations for PMIS in order to enhance project performance, especially in those sectors where effective coordination, data management, and timely decision-making are crucial for success.

Keywords:
project management information system (PMIS)

PMIS-IT

PMIS integration

PMIS collaboration

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Contents

1. INTRODUCTION

1.1 Background

In project management, Project Management Information Systems (PMIS) have become essential tools that provide a structured approach to managing project-related tasks, resources, and communication. These systems act as centralized hubs for data, enabling project managers to effectively coordinate and control project activities, particularly in complex, multi-stakeholder environments like construction and engineering. The architecture, engineering, and construction (AEC) industry, for instance, has heavily adopted PMIS to manage project complexities stemming from industry fragmentation and the diverse range of project stakeholders involved (Lee & Yu, 2012) .

PMIS consists of several key components: (i) the project management process model (or PM standard); (ii) the IT infrastructure, including data, hardware, and software, that supports the PM standard, processes data, and provides it to users; (iii) the end users, who are equipped with IT tools tailored to perform project management functions and tasks in an automated environment; and (iv) the necessary documentation. (Tulupov, 2020)

PMIS supports a broad range of project management functions, including scheduling, budgeting, resource allocation, and risk assessment. These systems allow for the integration of project data, helping managers streamline processes and make more informed, data-driven decisions. Research highlights that PMIS can drive productivity gains by improving collaboration and enhancing the quality of communication across project teams, which are critical for project success in fragmented industries like construction (Arnold & Javernick-Will, 2013) . For example, automated reporting and data visualization functionalities within PMIS offer real-time project insights, facilitating proactive risk management and ensuring that all stakeholders remain aligned on project goals (van Besouw & Bond-Barnard, 2021) .

Another key feature of PMIS is its capability for project monitoring and control. Effective project monitoring is vital for maintaining progress and achieving project milestones within time and budget constraints. PMIS often incorporates decision support tools, such as Earned Value Analysis (EVA), which enables project managers to monitor costs, assess performance against planned values, and forecast future project requirements (Hazır, 2014) . By aggregating performance data, PMIS allows project stakeholders to make timely interventions, minimizing deviations from project plans and improving overall project outcomes.

The demands of today's market for adaptable management, efficient production, interconnected objectives, and the alignment of diverse enterprise activities within a unified management system make it essential to have data support and to consolidate all business applications into a single information system (IS) for comprehensive enterprise management. Production activities form the foundation of enterprise operations. Growth in production is ensured through the establishment of a development strategy, executed within the scope of investment initiatives. The management of these processes is facilitated by tools such as Enterprise Resource Planning (ERP) systems and specialized Project Management (PM) software. (Tulupov, 2020)

Although ERP and PM software are often maintained separately due to issues such as incompatible information technologies (IT) and the limited functionality of the PM module within ERP systems, integrating these systems remains essential to maximize the effectiveness of a Project Management Information System (PMIS). This integration, by connecting ERP,

collaboration platforms, and other systems, facilitates seamless data sharing and enhances operational efficiency. (Tulupov, 2020)

In sectors like AEC (Architecture, Engineering, and Construction), the lack of interoperability often leads to redundant data entry and inefficiencies that reduce productivity. Research indicates that a collaborative, interoperable PMIS can reduce redundancy, minimize manual data entry errors, and promote smoother project execution by unifying information across platforms (Stewart & Mohamed, 2004). Such integration becomes increasingly critical as project sizes grow and stakeholders demand real-time data for informed decision-making. For instance, integration with ERP improves resource and financial management, while linking with scheduling software streamlines timelines and enhances planning accuracy (Lee & Yu, 2012).

With advancements in digital technology, Smart PMIS (SPMIS) now provide automated functionalities, which reduce the time spent on repetitive tasks and allow managers to focus on strategic activities like innovation and stakeholder engagement (van Besouw & Bond-Barnard, 2021) . This shift towards intelligent project systems has significant implications for the future of project management, promising more efficient project execution through automated reporting, improved data analytics, and real-time project dashboards. In increasingly competitive global markets, SPMIS offers a substantial advantage by enabling companies to manage complex project portfolios more effectively, responding to real-time data and adapting to project demands promptly.

1.2 Problem Statement

Despite the extensive adoption and recognized benefits of PMIS in enhancing project coordination and efficiency, there remains a notable gap in understanding how specific integrations with PMIS—such as connections with ERP systems, data visualization tools, and collaborative platforms—directly impact project outcomes. The general utility of PMIS in managing project data, improving communication, and supporting decision-making is well-documented (Lee & Yu, 2012) ; however, research that explores how specific software integrations enhance or constrain PMIS effectiveness is limited. This gap leaves project managers and stakeholders without a clear framework to assess which integrations are most beneficial or how to maximize the utility of integrated systems for improved efficiency, reduced redundancy, and better data management.

Key Challenges in PMIS Integration

One critical issue contributing to this gap is the lack of standardized approaches for integrating PMIS with other essential project management tools, leading to fragmentation and inefficiencies. For instance, in the architecture, engineering, and construction (AEC) industry, the absence of interoperability across different systems forces users to repeatedly re-enter data across platforms, introducing errors and wasting time (Arnold & Javernick-Will, 2013) . This lack of seamless integration disrupts workflows, hinders collaborative efforts, and makes it difficult to achieve the streamlined operations that PMIS is intended to support. Consequently, project teams may struggle with maintaining accurate, up-to-date project data, leading to compromised decision-making and missed opportunities for productivity gains.

Furthermore, while modern project environments increasingly demand real-time data access, most PMIS lack the advanced connectivity required for real-time data syncing across multiple platforms. This deficiency impacts critical functions such as risk management and resource allocation, where immediate access to accurate data is essential for responsive decision-making

(van Besouw & Bond-Barnard, 2021) . The limitations in real-time data integration restrict PMIS's ability to serve as a comprehensive solution, undermining its effectiveness and reducing the potential benefits of such systems.

Need for Research on Integration-Specific Outcomes

Addressing this gap requires focused research to evaluate the impacts of different PMIS integrations on project outcomes, identifying specific functionalities and metrics that are enhanced through integration. For example, studies on PMIS-ERP integrations could clarify how consolidating financial and project data impacts budget control and resource management, while analysis of PMIS-data visualization tool integrations may reveal benefits for reporting accuracy and stakeholder communication. Without this detailed understanding, organizations may face challenges in justifying integration investments and optimizing PMIS for their specific project needs.

1.3 literature review

1. Fulford & Standing (2014): Construction industry productivity and the potential for collaborative practice

Fulford and Standing's study explores the factors impacting productivity in the construction industry, particularly focusing on how collaboration through Project Management Information Systems (PMIS) can mitigate the inefficiencies caused by fragmentation. Their research suggests that PMIS, when integrated effectively, can enhance productivity by standardizing information and promoting collaborative practices across project teams. However, they note the industry's lag in technology adoption, which limits the potential benefits of PMIS. This study establishes the importance of collaboration within fragmented project environments and highlights PMIS as a potential solution for improving project outcomes in the construction sector.

2. Hazır (2014): A review of analytical models, approaches and decision support tools in project monitoring and control

Hazır's research focuses on the role of PMIS in project monitoring and control, with an emphasis on decision support tools like Earned Value Analysis (EVA). This study reviews various analytical models that support project managers in making real-time decisions by providing insights into project performance. Hazır's findings underline the value of PMIS in offering predictive capabilities, such as performance forecasting, that are crucial for large-scale, complex projects. The paper demonstrates that PMIS enhances project control functions by consolidating project data into actionable insights, allowing for timely interventions that can prevent cost and schedule overruns.

3. Lee & Yu (2012): Success Model of Project Management Information Systems in Construction

Lee and Yu develop a success model for PMIS in construction, grounded in the DeLone and McLean IS success model. Their research identifies key factors that contribute to the effectiveness of PMIS, such as system quality, information quality, and user satisfaction. This study emphasizes the importance of customizing PMIS to meet the unique demands of construction projects, which are often characterized by high fragmentation and a need for

robust information-sharing frameworks. Lee and Yu argue that PMIS plays a vital role in addressing inefficiencies in project coordination and improving decision-making by providing accurate, timely information. They conclude that a successful PMIS setup hinges on its ability to support seamless collaboration and information flow across project stakeholders.

4. Arnold & Javernick-Will (2013): Projectwide Access and Implementation of Construction Project Management Software Systems

Arnold and Javernick-Will investigate barriers and facilitators to the effective use of PMIS in the architecture, engineering, and construction (AEC) industry, with a focus on projectwide access and data interoperability. Their research identifies data re-entry and lack of standardization as significant obstacles to PMIS effectiveness. They suggest that collaborative, projectwide access to PMIS can improve efficiency by reducing redundant data entry and enabling more streamlined information-sharing across teams. The study emphasizes the need for interoperability and integration in PMIS, especially for industries like construction, where project data needs to flow seamlessly across different organizations and systems to support effective project management.

5. Van Besouw & Bond-Barnard (2021): Smart Project Management Information Systems (SPMIS) for Engineering Projects – Project Performance Monitoring & Reporting

Van Besouw and Bond-Barnard's research introduces the concept of Smart Project Management Information Systems (SPMIS), which integrate advanced digital tools, such as automation and predictive analytics, into traditional PMIS. Their study highlights how SPMIS can enhance project performance monitoring and reporting by automating repetitive tasks and providing real-time insights into project data. This approach aligns with Industry 4.0 trends, where data-driven decision-making is prioritized. They argue that SPMIS enables project managers to focus on strategic tasks by streamlining data processing and improving project data accessibility. This study is particularly relevant as it explores how digital advancements can transform PMIS from mere data repositories into intelligent systems that actively support project decision-making.

6. M Tulupov, M. A. (2020). METHODOLOGY FOR CONSTRUCTING A PROJECT Management INFORMATION SYSTEM BASED ON THE ENTERPRISE APPLICATION INTEGRATION

In this paper, Tulupov explores the integration of Enterprise Resource Planning (ERP) systems with project management software to create a comprehensive Project Management Information System (PMIS) through Enterprise Application Integration (EAI). The author reviews current barriers to integration, such as technological incompatibility and functional limitations of ERP-based project modules, which often result in isolated systems that limit data flow and operational efficiency. Tulupov proposes a structured EAI-based methodology to address these issues, aiming to improve automation, data sharing, and process management across project, program, and portfolio levels. This integration framework intends to enhance organizational efficiency, supporting improved project tracking, resource management, and strategic decision-making in complex enterprise environments.

The collective insights from these studies underscore PMIS's importance in addressing the challenges posed by fragmented project environments, especially in sectors like construction and engineering. Fulford & Standing (2014) and Lee & Yu (2012) highlight the productivity and collaboration gains that PMIS can facilitate in the construction industry, emphasizing the need for improved standardization and information-sharing. Hazır (2014) illustrates how

PMIS's decision support tools, like EVA, enhance project control functions, while Arnold & Javernick-Will (2013) discuss the critical role of interoperability in achieving PMIS effectiveness. Finally, Van Besouw & Bond-Barnard (2021) extend the PMIS concept by introducing Smart PMIS, which leverage digital technologies to enable more efficient, data-driven project management.

1.4 Objectives

The main objectives of this research are focused on evaluating and understanding the integration capabilities of Project Management Information Systems (PMIS) with various other software applications. This study seeks to investigate how these integrations contribute to project management efficiency, improved decision-making, and overall project success. By exploring these elements, this research aims to clarify which integrations are most beneficial and to provide actionable insights for optimizing PMIS deployment in complex project environments.

To achieve these objectives, the research will address the following key questions:

- What types of software are commonly integrated with PMIS?

This question aims to identify and categorize the types of software that PMIS frequently integrates with, such as Enterprise Resource Planning (ERP) systems, collaborative platforms, data visualization tools, and document management systems. Identifying these software types will offer a comprehensive view of the PMIS ecosystem and the common integration points that enhance its functionality.

- What are the methods used to integrate PMIS with other software applications?

This question examines the technical approaches used to achieve integration between PMIS and other software, such as API-based integration, cloud synchronization, and data standardization practices. Understanding these methods will help pinpoint the strengths and limitations of each approach, offering a practical guide for project managers on choosing the most effective integration techniques for their specific project needs.

- What are the specific benefits of integrating PMIS with other software applications?

By examining the tangible benefits of PMIS integrations, this research will explore how integration enhances PMIS functionalities, including improved data accessibility, real-time reporting, better collaboration, and more streamlined workflows. This question aims to assess how integrated PMIS systems contribute to more informed decision-making, reduced redundancy, and overall operational efficiency.

This study also incorporates insights from a visual representation of PMIS functionalities, as shown in the figure below, sourced from "Smart Project Management Information Systems (SPMIS) for Engineering Projects – Project Performance Monitoring & Reporting". This figure illustrates the functionalities supported by several popular PMIS platforms—MS Project Online, Oracle Primavera, CCS, Oracle Aconex, and Trimble—and highlights their compatibility with other software applications.

PMIS FUNCTIONS	MS Project Online	Oracle/Primavera	CCS	Oracle/Aconex	Trimble
1. WBS & Gantt chart	✓	✓	✓		
2. CPM (critical path method)	✓	✓	✓		
3. Time sheet system	✓	✓			
4. Task management (social collaboration)		✓		✓	✓
5. Cost and financial control	✓	✓	✓		✓
6. Risk management		✓			
7. Document management		✓		✓	✓
8. Field management		✓		✓	✓
9. Automated data inputs (from field instruments)					
10. Resource levelling or histogram	✓	✓	✓		
11. Project performance data reporting/dashboards	✓	✓	✓	✓	✓
12. Workflow management				✓	✓
13. Customisable project reports	✓	✓	✓	✓	✓
14. Live data reporting/cloud based	✓	✓	✓	✓	✓
15. Project portfolio management (ppm)	✓	✓			
16. Ability to use data from past projects					
17. Compatible with other software applications	✓	✓	✓	✓	✓
18. What if analysis (scenario planning)	✓	✓	✓		
19. Earned value and s-curves	✓	✓	✓		
20. BIM & drawing mark-up interface			✓	✓	✓
SCORE :	12	15	11	9	10

Figure 1 Comparative Analysis of PMIS Functional Capabilities

Note. Adapted from "Smart Project Management Information Systems (SPMIS) for Engineering Projects – Project Performance Monitoring & Reporting," by J. van Besouw & T. Bond-Barnard, 2021, University of Pretoria.

The figure provides a comparative overview of each platform's capabilities, demonstrating significant differences in the integration of key functionalities such as document management, cost control, and project performance reporting. Notably, it underscores "Compatibility with other software applications" as a critical function that varies across PMIS solutions, which is directly relevant to the objectives of this research. This comparative data forms a foundation for exploring how specific integrations contribute to overall project efficiency and what gaps still exist in current PMIS offerings. **MS Project Online** and **Oracle Primavera** generally cover more functions, making them comprehensive tools for project management needs.

Each PMIS software—MS Project Online, Oracle Primavera, CCS, Oracle Aconex, and Trimble—is assessed for its support of these functions. The checkmarks in each column indicate that a software package supports the respective function. The scores at the bottom provide a summary of each software's functional coverage, which can help in understanding the strengths and weaknesses of each tool for project management needs.

Since almost every PMIS in this comparison supports compatibility, it underscores that integration is a standard and expected feature in high-quality project management software. By

addressing these research questions and analyzing the functionalities shown in the figure, this study will contribute to a more refined understanding of how PMIS can be optimally integrated with other tools, ultimately supporting project managers and stakeholders in making strategic software integration decisions.

1.5 Thesis Structure

This thesis follows a systematic and coherent structure, designed to provide a comprehensive exploration of Project Management Information Systems (PMIS) and their integration into project management processes. It begins by introducing the role of PMIS in addressing key challenges in project management, such as coordination, data accuracy, and stakeholder collaboration, particularly in complex and multi-stakeholder environments. The introduction also identifies a critical gap in understanding how specific PMIS integrations influence project outcomes, laying the groundwork for this research. The objectives of the thesis are outlined to focus on identifying common types of PMIS integrations, analyzing their implementation methods, and assessing their tangible benefits to project management.

The research methodology employed is presented as a cornerstone of the thesis, detailing the systematic approach adopted to explore the integration of Project Management Information Systems (PMIS). A systematic literature review (SLR) forms the foundation of this research, chosen for its ability to consolidate and synthesize findings from diverse studies. The SLR approach ensures a comprehensive, rigorous, and unbiased examination of PMIS integrations, enabling the identification of patterns, key insights, and emerging trends across a broad spectrum of scholarly work.

The thesis employs the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to guide the SLR process. The PRISMA framework enhances the transparency, replicability, and reliability of the review, ensuring that each stage of study selection and analysis is meticulously documented. This structured methodology begins with the identification phase, where extensive database searches are conducted using predefined keywords and Boolean operators to capture relevant literature. Scopus, as the primary database, provides access to a vast repository of peer-reviewed articles, ensuring high-quality and comprehensive data sources. Supplementary searches on platforms like ResearchGate further enhance the scope, allowing for the inclusion of relevant preprints and author-provided materials. By leveraging the PRISMA framework and SLR approach, the research provides a well-structured analysis that aligns with the research objectives. It ensures that the conclusions drawn are not only based on high-quality evidence but also reflective of the diverse and multi-faceted nature of PMIS integrations.

Building on the findings, the discussion delves deeper into the implications of PMIS integrations for project management practices. It explores how these integrations address critical aspects such as real-time data sharing, resource optimization, and stakeholder alignment. The discussion also highlights challenges like interoperability issues, cost implications, and the need for standardization in integration practices. By critically evaluating these factors, the thesis provides a balanced view of the transformative potential and limitations of PMIS integrations.

The conclusion synthesizes the key insights of the research, summarizing how PMIS can be optimized through strategic software integration. It reflects on the implications of the findings for project managers and industry practitioners, offering practical recommendations for leveraging PMIS integrations to enhance project performance. Additionally, the thesis acknowl-

edges its limitations and suggests avenues for future research, particularly focusing on the potential of incorporating emerging technologies like artificial intelligence (AI) and machine learning (ML) into PMIS to further enhance their capabilities.

2. METHODOLOGY

2.1 Research Design

To comprehensively investigate Project Management Information Systems (PMIS), a Systematic Literature Review (SLR) approach was selected as the research design for this thesis. SLR is particularly well-suited for synthesizing findings from diverse studies, enabling a structured examination of PMIS features, functions, and implementation challenges across various contexts and industries.

SLR was chosen because it allows for a methodical and comprehensive approach to consolidating PMIS research, which spans across disciplines and organizational settings. This method provides an effective means of addressing the complexities and multifaceted aspects of PMIS, which is critical for developing a cohesive understanding of PMIS design factors, key dimensions, and the challenges faced during implementation.

To examine PMIS effectively, it's essential to consolidate diverse research findings that cover various PMIS dimensions, such as decision-making support, resource management, and collaboration tools. PMIS research spans across multiple studies and industries, making it challenging to gather coherent insights through traditional, single-source research. Therefore, a Systematic Literature Review (SLR) approach was chosen as the primary research design to address these complexities in a structured and comprehensive manner.

To ensure the systematic transparency of this review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework has been selected to guide the SLR process. PRISMA is widely recognized for its structured approach to literature reviews and has been shown to improve the clarity, transparency, and replicability of reviews by clearly outlining each phase of article selection and data extraction (Moher et al., 2009).

The PRISMA framework follows a four-phase process that ensures systematic identification, screening, and synthesis of relevant studies. Here is an outline of each phase as applied to this research:

1. **Identification**: The first phase involves conducting a comprehensive database search, in this case using Scopus, to gather all potentially relevant articles. The identification phase includes using predefined keywords, such as "Project Management Information System" and "PMIS design," to capture a broad range of studies related to PMIS features, dimensions, and challenges.
2. **Screening**: After identifying relevant studies, the screening phase involves filtering articles based on predetermined criteria (e.g., article relevance, peer-reviewed status). Titles and abstracts are reviewed to eliminate studies that do not meet the scope of PMIS research, such as those focused on unrelated systems or theoretical perspectives lacking empirical data.
3. **Eligibility**: In the eligibility phase, full-text articles are reviewed to assess their alignment with inclusion criteria, such as specific relevance to PMIS dimensions, user experience, and implementation challenges. Studies that meet all criteria are retained for final analysis, while those with limited relevance or methodological rigor are excluded.
4. **Inclusion**: The final phase of the PRISMA process is the inclusion of studies that meet all criteria. These articles form the basis of the synthesis, allowing for a comprehensive analysis of key themes in PMIS research.

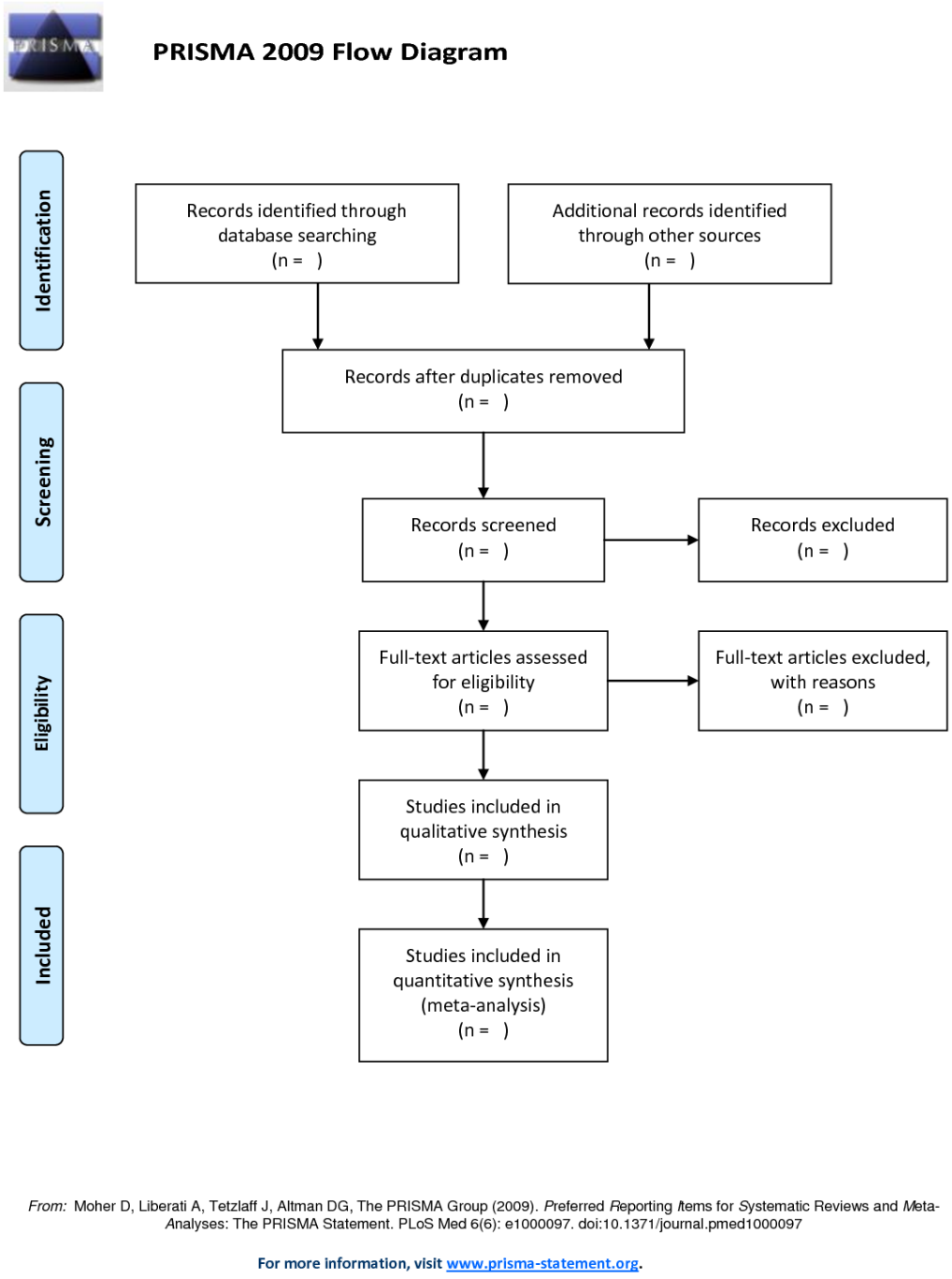

Figure 2 Prisma Flow Diagram

Note. From "Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement," by D. Moher, A. Liberati, J. Tetzlaff, D. G. Altman, & The PRISMA Group, 2009, PLoS Medicine, 6(7), e1000097. Copyright 2009 by The PRISMA Group.

2.2 Data Sources

- **Database Selection**

For this study, Scopus was selected as the primary database due to its extensive and reputable collection of peer-reviewed research articles and relevant literature on Project Management Information Systems (PMIS) and PMIS Design. Scopus was selected as the primary database due to its unique strengths:

Comprehensive Coverage of High-Quality Research: Scopus is known for its extensive indexing of peer-reviewed literature across a broad range of disciplines, including technology, business, engineering, and social sciences. This comprehensive coverage ensures that the review can access diverse studies related to PMIS, spanning various applications, industries, and methodologies. As PMIS research intersects with multiple fields, Scopus's wide scope allows for a thorough exploration of these dimensions.

Focus on Peer-Reviewed, Credible Sources: Scopus is exclusively focused on peer-reviewed content, which upholds the quality and reliability of studies included in this review. Unlike other databases that may include non-peer-reviewed materials, Scopus's strict indexing criteria help ensure that only credible and scientifically validated studies are considered, aligning with the transparency required in a systematic review.

Robust Citation Tracking and Impact Metrics: Scopus's built-in citation tracking and impact metrics allow the review to identify influential studies and measure the academic impact of selected articles. This feature provides insights into the relevance and recognition of studies within the academic community, which can help prioritize highly cited or impactful research within the PMIS field.

In addition to Scopus, ResearchGate was also used as a supplementary data source. ResearchGate is a popular academic network that allows researchers to share and access scholarly articles, fostering academic collaboration and discussion.

While Google Scholar was reviewed as a possible source due to its open access and broad scope, it was ultimately excluded for this review. Google Scholar indexes a wide variety of sources, including non-peer-reviewed content, making it less ideal for a rigorous, systematic literature review focused on peer-reviewed, high-quality sources. Additionally, Google Scholar's limitations in advanced search functionalities and filtering options can affect the replicability and systematic nature of the search process.

2.3 Keywords and Search Strategy

The search process relied on a set of carefully selected core keywords to ensure direct relevance to the study's focus, supplemented by supporting keywords to capture a broader range of studies addressing different PMIS dimensions.

Core Keywords: These keywords represent the primary focus of the literature search, targeting articles directly addressing PMIS. They were selected to capture foundational studies related to PMIS in project management.

- "Project Management Information System" OR "PMIS"
- "PMIS integration" OR "Project Management Information System integration"

Supporting Keywords: These additional keywords were chosen to include studies discussing specific PMIS features, design aspects, and implementation challenges. By expanding the search to these terms, the review captures studies that may use alternative terminology while still contributing valuable insights into PMIS.

- "PMIS challenges" OR "Barriers to PMIS implementation"
- "PMIS decision-making support" OR "Project Management Information System decision support"
- "PMIS implementation" OR "Project Management Information System implementation"

Table 1 below provides a detailed summary of the keywords used to identify the studies:

Category	Keywords	Purpose
Core Keywords	"Project Management Information System "or "*PMIS*"	**To capture foundational studies directly focused on PMIS, ensuring comprehensive insights into its overall role.**
	"PMIS integration" OR "Project Management Information System integration"	**To identify research that examines how integration influences system usability, flexibility, and effectiveness in optimizing project management processes.**
Supporting Keywords	***"PMIS challenges" OR "Barriers to PMIS implementation"***	**To identify studies discussing obstacles in PMIS adoption.**
	"PMIS decision-making support" OR "Project Management Information System decision support"	**To capture research focused on PMIS's role in enhancing decision-making processes.**
	"PMIS implementation" OR "Project Management Information System implementation"	**To examine studies that detail PMIS deployment highlighting best practices and factors affecting successful implementation.**

Table 1 Keyword Categorization and Research Objectives for Literature Review

- **Search Strategy and Snowballing Technique**

The search strategy was executed in Scopus, chosen as the primary database due to its extensive coverage of peer-reviewed literature in fields relevant to PMIS. Additional searches were conducted on ResearchGate to access author-provided full texts and preprints that might not be available in other databases. The search was conducted as follows:

Keyword Combinations: The selected core and supplementary keywords were combined using Boolean operators (e.g., AND, OR) to refine and broaden the search as needed.

Date Range and Document Type Filters: The search was limited to articles published in the past decade to ensure that the most relevant, up-to-date findings were included.

Snowballing Technique: To enhance the comprehensiveness of the search, both backward and forward snowballing techniques were used.

- Backward Snowballing: The reference lists of initially selected articles were examined to identify influential, foundational studies that might not have appeared in the initial keyword search. This step ensured that important, frequently cited research on PMIS was included.
- Forward Snowballing: Recent articles that cited the selected studies were identified using Scopus citation tracking. This approach allowed the review to capture emerging trends, current developments, and new applications in PMIS that build upon earlier research.

2.4 Inclusion and Exclusion Criteria

The purpose of establishing clear inclusion and exclusion criteria is to ensure that the systematic literature review remains focused on high-quality, relevant studies that directly contribute to understanding key aspects of Project Management Information Systems (PMIS). By setting these criteria, the review process prioritizes articles that align closely with the study's objectives, filtering out irrelevant or lower-quality sources and thereby enhancing the reliability and precision of the findings.

Inclusion Criteria

The eligibility criteria were established to refine the selection of articles and identify studies that are directly pertinent to the research keywords. The articles selected for this review met specific inclusion criteria to ensure that they:

Language and Peer Review: Are written in English and have undergone a peer-review process to ensure academic rigor.

Relevance to PMIS: Discuss Project Management Information Systems specifically, focusing on design, operational effectiveness, decision-making support, or other critical PMIS functions.

PMIS Dimensions and Functionality: Include specific information on PMIS dimensions, such as decision support, collaboration, resource allocation, or integration within project management frameworks.

Exclusion Criteria:

Non-Peer-Reviewed Sources: Exclude book chapters, conference abstracts, and other non-peer-reviewed sources to maintain high-quality standards.

Irrelevant Topics: Exclude papers that are unrelated to PMIS or only marginally mention project management information without examining PMIS functionality or effectiveness.

Editorials, Opinions, or Anecdotes: Exclude papers that are opinions, editorials, commentaries, or anecdotal reflections lacking empirical data.

Each inclusion and exclusion criterion was carefully chosen to maintain the review's focus on high-quality, relevant studies that directly support the research objectives of analyzing PMIS design, functionality, and effectiveness. The inclusion criteria ensure that selected articles provide empirical insights into PMIS dimensions, such as decision-making and resource management, and are grounded in peer-reviewed research to uphold credibility. Exclusion criteria, such as omitting non-peer-reviewed sources or overly specific case studies, help filter

out studies that lack generalizability or empirical reliability, ensuring the review remains aligned with the goal of understanding PMIS applications and challenges.

3. RESULTS

3.1. PRISMA-Based Study Selection

This section details the systematic approach used to identify, screen, and select studies for inclusion, based on the PRISMA framework. The PRISMA process ensures transparency and replicability in the study selection, providing a clear pathway from an initial broad dataset to a focused set of articles that address the specific research objectives.

Identification: An initial search was conducted using keywords related to PMIS and interoperability with other IT systems. This search yielded a total of 24 articles, including studies from previous years to capture trends over time. The focus was on recent studies to ensure relevance to current PMIS integration practices.

Screening: To refine the dataset, articles deemed too outdated were excluded to maintain relevance. Additionally, any duplicate studies identified in the initial search were removed, resulting in 21 articles. At this stage, studies were further screened based on exclusion criteria, which required articles to specifically address interoperability between PMIS and other IT systems. Consequently, 3 articles that did not align with this context were excluded, leaving 18 articles.

Eligibility: Since the database provided full-text access to all articles initially identified, no articles were excluded due to access limitations. This ensured comprehensive content analysis across the full dataset.

Inclusion: Among the remaining 18 articles, a further qualification step was conducted to identify studies most relevant to the specific context of PMIS interoperability. Ten articles were found to closely align with the focus of the study, specifically addressing the integration between PMIS and other software systems. Of these, 6 articles were ultimately selected as the most relevant and high-quality studies, meeting all inclusion criteria and providing detailed information on the integration of PMIS with other IT systems. Table 2 below lists key articles referenced in the research.

	Article Title	Authors	Year
1	Construction industry productivity and the potential for collaborative practice	Richard Fulford, Craig Standing	2013
2	A review of analytical models, approaches and decision support tools in project monitoring and control	Öncü Hazır	2014
3	Projectwide access: key to effective implementation of construction project management software systems	Paul Arnold1 and Amy Javernick-Will, A.M.ASCE	2013
4	Success model of project management information system in construction	Seul-Ki Lee, Jung-Ho Yu	2012
5	Smart project management information systems (SPMIS) for engineering projects – project performance monitoring & reporting	John van Besouw , Taryn Bond-Barnard	2021
6	Methodology for constructing a project management information system based on the enterprise application integration	M. A. Tulupov,	2020

Table 2 Key Studies on Project Management Information Systems (PMIS)

3.2. Key PMIS Integrations

Out of the final set of articles selected, each study that discussed PMIS integration with additional systems was categorized by system type. This breakdown illustrates how frequently each type of integration is highlighted within the literature, revealing the relative focus on different PMIS integration practices in current research.

Collaboration and Communication :

In reviewing the relevant literature, several studies highlight the integration of Information and Communication Technology (ICT) within PMIS as a critical productivity enabler across the supply chain. The integration of ICT facilitates real-time data flows, thereby improving decision-making and project management practices. Similar to the Enterprise Resource Planning (ERP) systems used in other sectors, standardizing ICT practices and aligning them with PMIS could lead to significant productivity gains and quicker responses to project demands. (Dossick & Sakagami, 2008).

These core functions of PMIS highlight the critical role of effective communication and collaboration tools in uniting diverse project teams and streamlining processes. A prime example of such a tool is Aconex, which extends these foundational capabilities by offering advanced communication and task management features tailored to address integration challenges in multifaceted projects.

Aconex

Aconex's communication and task management capabilities play a crucial role in overcoming integration barriers. According to a study by Son et al. (2016), Aconex's platform allows users to create workflows and track communication, ensuring that each project participant is informed of updates in real-time. This transparency improves accountability and enables proactive management, which is essential in large, complex projects that involve multiple organizations.

Share point

SharePoint significantly reduces data fragmentation by serving as a central repository for all project-related documents, such as drawings, contracts, and reports.

Web-based Project Management Systems (WPMS)

Further studies emphasize that Web-based Project Management Systems (WPMS), when integrated into PMIS, can streamline document management and reduce communication bottlenecks. This integration promotes smoother data flow across platforms and organizations, addressing the communication challenges inherent in the fragmented structure of the Architecture, Engineering, and Construction (AEC) industry (Stewart & Mohamed, 2004).

WPMS addresses data fragmentation by centralizing project documents, communications, and scheduling tools within a single online platform. Nitithamyong and Skibniewski (2003) note that WPMS often functions through application service providers (ASPs), allowing organizations to rent or lease the software, which can lower costs and simplify the deployment of a centralized data hub. This arrangement minimizes data silos and enhances document

accessibility, making it easier for teams to retrieve information and collaborate in real-time across project stages (Nitithamyong & Skibniewski, 2003).

Despite these advantages, WPMS implementation faces certain challenges like internet reliability and cybersecurity risks are significant which are concerns with WPMS, as access depends on stable online connectivity, and sensitive project data is vulnerable to potential breaches (Nitithamyong & Skibniewski, 2003).

The literature also briefly mentions a shift from traditional enterprise-based PMIS, generally controlled by general contractors, toward a collaborative, project-based model. This approach would allow all project team members, including subcontractors and consultants, direct access to project data, reducing inefficiencies such as data re-entry and enhancing overall team coordination and communication in alignment with the ICT-enabled improvements described above (Dossick & Sakagami, 2008).

Supply Chain Management (SCM) Integration :

The literature emphasizes the role of Project Management Information Systems (PMIS) in enhancing Supply Chain Management (SCM) within the construction sector by integrating various IT-enabled tools. Effective SCM through PMIS allows for the management of products, information, and financial flows, which helps reduce traditional inventory requirements and minimizes waste. This collaborative approach within PMIS promotes information standardization and trust across the supply chain, ultimately lowering errors and costs by improving data consistency and accuracy (Mehrjerdi, 2009; Kamath & Roy, 2007).

Additionally, industry-wide standardization has been highlighted as a key element in promoting interoperability across diverse PMIS platforms. Standards such as Industry Foundation Classes (IFCs) facilitate seamless data exchange between systems, reducing the need for repetitive data re-entry. This standardization fosters cross-platform collaboration and ensures that project teams can efficiently share information across the supply chain, streamlining processes and improving coordination (Hu & Zhou, 2009).

Moreover, the integration of automated data entry and feedback loops within PMIS plays a crucial role in modern SCM practices. Automated data capture—such as 3D laser scanning that syncs with project schedules—reduces the need for manual data input, ensuring timely and accurate updates. This continuous feedback loop allows for ongoing project monitoring, enhancing data reliability and promoting more efficient handling of project data. Such automation is central to the Smart PMIS (SPMIS) model, which is designed to streamline SCM activities and support data-driven decision-making across the project lifecycle (Braglia & Frosolini,2014).

This inter-organizational integration supports more accurate cost estimations, supplier alignment, and enhanced productivity across projects, which ultimately leads to more synchronized project workflows and improved project outcomes (Hadaya & Pellerin, 2010; Bankvall et al., 2010).

Inter-Organizational IT Integration and Interoperability in PMIS

The evolution of PMIS toward greater interoperability is a critical aspect of inter-organizational IT integration. As PMIS systems evolve to incorporate both older tools (such as CAD and scheduling applications) and newer Information and Communication Technology (ICT) tools,

they provide a unified view of project data that enables real-time information sharing across all project phases. This progression towards interoperability allows PMIS to serve as a central hub for project data, facilitating coordination across different platforms and mitigating delays caused by isolated data silos (Froese, 2010).

The use of ASP-based, web-enabled PMIS further enhances interoperability by enabling location-independent access and supporting reliable data exchange. ASP-based PMIS can integrate with essential project tools like CAD and scheduling software, improving coordination across project teams by providing a standardized platform for data sharing.

Decision Support Systems (DSS):

The literature highlights the valuable role of integrating Decision Support Systems (DSS) within Project Management Information Systems (PMIS) to manage complex, multi-project environments effectively. DSS integration supports optimal scheduling and resource allocation, providing project managers with the tools to handle interdependencies and uncertainties across multiple, concurrent projects. By facilitating the coordination of resources and timelines, DSS integration enables a more efficient approach to managing overlapping project demands in multi-project settings (Hans et al., 2007).

Additionally, model-driven DSS integrated within PMIS serves as a powerful tool for enhancing decision-making through quantitative modelling capabilities. These model-driven systems allow for sensitivity analysis, scenario simulations, and dynamic resource optimization, which help project managers test various scenarios and adapt their strategies based on data-driven insights. This integration bridges the gap between theoretical models and practical applications in project management, offering a structured approach to addressing complex project requirements and improving decision-making accuracy in dynamic environments (Hahn & Kuhn, 2012).

This integration of model-driven DSS within PMIS also emphasizes the need for specialized tools that streamline complex data management tasks. Tools like @Risk and Crystal Ball (Oracle) build upon this foundation by specifically targeting risk-related data, providing a cohesive platform to manage uncertainties and support informed decision-making in project environments.

At risk (@Risk)

@Risk addresses data fragmentation by consolidating risk-related data into a single platform where uncertainties across project areas (like cost, schedule, and resource allocation) can be analyzed holistically. By integrating Monte Carlo simulations, @Risk enables construction managers to model various project scenarios and assess risk probabilities, providing a probabilistic framework that supports more informed decision-making. According to Metzger et al. (1998), @Risk's capacity to handle complex data and run simulations within Excel makes it ideal for analyzing interconnected project risks without needing separate, isolated risk management systems (Metzger et al., 1998).

Crystal Ball (Oracle)

Crystal Ball's sensitivity analysis features, such as tornado charts, allow project managers to identify high-risk variables that could significantly impact project outcomes. Seňová et al. (2023) observed that these visual tools enhance risk assessment by focusing on the most critical risk factors, enabling managers to allocate resources effectively for risk mitigation. This focus

on high-impact variables is particularly useful in fragmented project settings, where risks may arise from various departments or stakeholders (Seňová et al., 2023).

Smart Project Management Information Systems (SPMIS):

Recent developments in big data creation and storage are paving the way for new digital tools in project management. To effectively track projects, up-to-date and accurate data is essential. This data needs to be collected and presented to stakeholders for review, often in reports or on digital dashboards. However, creating these reports can be difficult and time-consuming since data is frequently spread across different software. Advances in digital technology offer the possibility of a "Smart" PMIS (SPMIS) that can gather, analyze, and interpret data from multiple sources to help project managers monitor complex projects more easily. Data drives the analytics that enable automated project management functions, giving project offices with data access a competitive edge over those without it. (van Besouw & Bond-Barnard, 2021)

Projects are growing more complex technically, with increasing pressure to deliver faster and at lower costs due to intense competition and heightened expectations from stakeholders. Engineering firms, which often handle multiple projects at once, face significant challenges in tracking and managing these projects effectively. Current PMIS often fall short of addressing these needs comprehensively, as data is frequently fragmented across various software tools and must be manually transferred between applications. This process is not only labor-intensive but also introduces a high risk of error.(van Besouw & Bond-Barnard, 2021)

The lack of real-time, accurate data impedes strategic decision-making and increases project risks, impacting resource allocation, profitability, and stakeholder satisfaction. However, recent advances in big data technology present a significant opportunity to develop a “Smart” PMIS (SPMIS) that integrates data from various sources and applications seamlessly. An SPMIS could automate data capture and analysis, providing project managers with up-to-date insights and enabling them to manage complex projects with greater precision. By consolidating data into a unified platform, an SPMIS would facilitate proactive decision-making, real-time reporting, and efficient resource planning.(van Besouw & Bond-Barnard, 2021)

While many PMIS systems and theoretical models exist, they often lack the capability to provide a fully integrated, intelligent solution. Developing a comprehensive SPMIS that supports automation, data analytics, and real-time feedback would not only enhance project management efficiency but also give companies a competitive edge in dynamic and demanding project environments. (van Besouw & Bond-Barnard, 2021)

The concept of a Smart Project Management Information System (SPMIS) was introduced by Jaafari and Manivong (1998), who described an advanced PMIS designed to support more complex projects. They used the term "smart" to signify the enhanced intelligence of this system compared to existing solutions on the market. The authors argued that an SPMIS should provide live, real-time data that is easily accessible to project stakeholders, be flexible enough to handle various types of data and information, and offer extensive functionalities. Moreover, the system should possess sophisticated analytical capabilities to oversee the project lifecycle effectively. When assessing the PMIS systems available at that time, Jaafari and Manivong noted limitations, particularly in microcomputers, which lacked the processing power required to run an SPMIS. They also pointed out that most PMIS solutions on the market were not designed to enable proactive project management, nor did they integrate essential evaluations in areas such as cost, time, and risk management, which the authors viewed as fundamental to project success (Jaafari & Manivong, 1998).

The conceptual model developed using the findings from the research study, *Smart Project Management Information Systems (SPMIS) for Engineering Projects – Project Performance Monitoring & Reporting* by John van Besouw and Taryn Bond-Barnard (2021) from the University of Pretoria, is provided in Appendix A.

At the core of the Smart Project Management Information System (SPMIS) lies a centralized, cloud-based data management system, which allows data from multiple projects to be consolidated in one place. This centralized SPMIS is designed with artificial intelligence (AI) principles, utilizing artificial neural networks and machine learning algorithms to identify patterns in project performance data and deliver actionable insights to project stakeholders. The system should be capable of handling various data types, making information easily accessible and viewable in a single platform. Additionally, it should present data as project reports in intuitive formats, such as graphs, charts, and diagrams, to support stakeholders in making informed decisions and tracking project progress effectively. . (van Besouw & Bond-Barnard, 2021).

Building Information Modelling (BIM) :

Building Information Modelling (BIM) is a transformative information and communication technology used in architecture, engineering, construction, and operations (AECO). It integrates various aspects of project management such as design, scheduling, cost estimation, and quality control. BIM offers functionalities like data visualization, workflow analysis, and simulation to enhance collaboration and decision-making across multidisciplinary project teams. BIM integration with Project Management Information Systems (PMIS) creates a centralized framework for managing project data and processes. This integration supports BIM Information Flow, enabling seamless sharing of modelling data among project teams. BIM-based PMIS also facilitates workflows such as clash detection, scheduling, and resource allocation by utilizing data-driven insights from BIM models. The synergy between BIM and PMIS enhances overall project lifecycle management by improving interoperability, enabling collaboration, and aligning processes with project objectives. (Ma et al., 2018).

The paper, *Conceptual Framework and Roadmap Approach for Integrating BIM into Lifecycle Project Management* by Ma et al. (2018), presents a case study involving the implementation of a Building Information Modelling (BIM)-based approach in the lifecycle management of a building refurbishment project in Chengdu, China. The case study focuses on the refurbishment of an office building in Chengdu, China, where BIM was systematically integrated into the project lifecycle to address complex project requirements. The project's goals included developing a BIM roadmap to guide lifecycle management and establishing a BIM-based PMIS to enhance collaboration and communication among stakeholders.

The study adopted an ethnographic action research approach, with researchers acting as BIM consultants for six months during the design phase. This hands-on involvement enabled the development of a comprehensive BIM roadmap, which linked functional applications such as clash detection, quantity surveying, and schedule simulation (4D/5D modelling) to project objectives. The roadmap evolved through a "BIM Model Chain," progressively integrating data from design to construction and operations, ensuring seamless transitions between project phases.

A centralized BIM-based PMIS platform was established to consolidate project data, resolve interoperability challenges, and facilitate real-time collaboration among multidisciplinary teams. Regulatory and organizational measures, such as the "Project BIM Standard," governed

the platform's use, ensuring accuracy and standardization in data management and decision-making.

Key findings included the ability of BIM to enhance efficiency by consolidating data, improving workflows, and supporting dynamic decision-making. Functional applications like clash detection and schedule simulation optimized resource use and minimized risks. The study demonstrated that BIM integration fosters collaboration, streamlines processes, and establishes a systematic approach to lifecycle project management.

This case exemplifies the transformative impact of BIM-based PMIS in addressing traditional inefficiencies in project management and offers a structured model for lifecycle integration in the Architecture, Engineering, Construction, and Operations (AECO) industry. (Ma et al., 2018).

Such platforms play a pivotal role in enabling project teams to transition from fragmented workflows to unified systems that support all phases of the project lifecycle. One prominent example of this is Autodesk Revit, which effectively addresses data fragmentation by providing a centralized environment for design and documentation.

Autodesk Revit

Autodesk Revit effectively tackles data fragmentation by providing a unified platform for design, documentation, and collaboration. Huang (2017) highlights Revit's ability to consolidate 2D and 3D data into an intuitive, visual model, which reduces the need for secondary design work and minimizes the risk of errors caused by data silos. By integrating information from multiple disciplines (e.g., architectural, structural, and mechanical), Revit allows teams to avoid clashes between elements and coordinate more seamlessly, ultimately reducing the design and construction timeline (Huang, 2017).

Autodesk Revit also enhances collaborative work environments by allowing real-time updates and enabling multiple stakeholders to access the project model simultaneously. Garagnani and Luciani (2011) noted that Revit's parametric modelling allows teams to implement changes that automatically propagate throughout the model, ensuring consistency and coordination across disciplines. This feature supports effective communication and real-time data sharing, essential for maintaining project alignment and reducing the delays often associated with fragmented data (Garagnani & Luciani, 2011).

Navisworks

Navisworks addresses data fragmentation by enabling the integration of 3D BIM models from different software platforms, such as Revit, Tekla, and AutoCAD, into a single cohesive environment. This feature allows for centralized model visualization and streamlined data sharing among project stakeholders. Brokaw (2012) observed that Navisworks effectively facilitates the exchange of project information, enabling cross-discipline collaboration and minimizing data silos by consolidating models from multiple platforms. This integration helps prevent conflicts that could arise from inconsistent or incomplete data sources, providing a clearer view of the project as a whole (Brokaw, 2012).

Navisworks faces certain challenges, particularly in integrating with broader enterprise systems like ERP for cost control. While its focus on design and visualization makes it excellent for coordination, extending Navisworks into areas such as budget and procurement management requires additional configuration. Xu et al. (2019) noted that while Navisworks is effective for model integration and clash detection, integrating cost and schedule data from ERP or other

PMIS platforms requires advanced customization, which can increase implementation complexity (Xu et al., 2019).

3.3. Software Integrated with PMIS

In recent years, Project Management Information Systems (PMIS) have become increasingly sophisticated, integrating a variety of software to enhance project management capabilities across diverse functions. These integrations allow PMIS to streamline processes, improve real-time collaboration, and optimize decision-making, particularly in complex, multi-stakeholder environments. The following subsections outline the primary types of software integrated with PMIS, highlighting how each supports specific project functions, from resource management and financial control to data visualization and communication. This overview reflects the crucial role of software integration in maximizing the efficiency and functionality of PMIS in project management contexts.

In global practice, the following applications are commonly used to construct a Project Management Information System (PMIS): standalone project management (PM) software, the PM module within an ERP system, or a combination of both, which may be managed either as integrated or separate systems. (Tulupov, 2020)

Project Management Software Systems:

This category includes systems like **Enterprise Resource Planning (ERP)** programs, **Web-based Project Management Systems (WPMS)**, Project Management Application Service Providers (PM-ASPs), and specialized project management software solutions such as **Microsoft Project** and **Oracle Primavera**. Larger organizations in the construction sector may use **SAP,** or other custom-built systems tailored to meet their specific project management, scheduling, and document handling needs.

ERP systems are widely used in the construction industry for their ability to unify various project functions, including finance, scheduling, and human resources, into a single, cohesive platform. ERP systems offer comprehensive data integration and facilitate real-time decision-making across departments.

The primary information system (IS) can be either the PM software or the ERP system, although their roles and functions differ significantly. ERP systems are primarily responsible for financial control and resource management, while PM software is focused on detailed project planning, re-planning, project optimization, portfolio and program management (PPP), progress analysis, and project reporting. Project-related data fields include the project plan, budget, costs, resources, and actual data. Data transmission typically occurs as follows: resources, budget, and costs are sent in one direction from the ERP system, while project structures, plans (including the work breakdown structure, tasks, and resource assignments), and actual project data flow in both directions. (Tulupov, 2020)

WPMS are increasingly popular in construction for their ability to facilitate real-time data access and collaboration across geographically dispersed teams. WPMS enables stakeholders to communicate effectively, share documents, and manage project schedules from any location with internet access. (Tulupov, 2020)

As derived from the article *Smart Project Management Information Systems (SPMIS) for Engineering Projects – Project Performance Monitoring & Reporting* by Van Besouw and Bond-Barnard (2021), an online search on the software review platform Capterra identified over 500 project management software applications (Capterra, 2019). Given the extensive

range of options, it was not feasible to examine each one in detail. Instead, findings from a survey conducted by Ilyas (2013) were used to narrow down the focus. This survey involved approximately 25 project managers across the construction and energy/oil industries in regions including Europe, the Middle East, and Africa (EMEA). Combined with insights from this study, a shortlist of five PMIS tools was established for in-depth review. Each PMIS—CCS Candy, MS Projects, Primavera, Aconex, and Trimble (Project Sight)—was evaluated through methods such as consultations with software sales representatives, analysis of product brochures, examination of online content, and viewing software demonstration videos.

Table 3 below, adapted from *Smart Project Management Information Systems (SPMIS) for Engineering Projects – Project Performance Monitoring & Reporting* by Van Besouw and Bond-Barnard (2021), illustrates the shortlist of PMIS tools identified through the survey results and research findings.

Software Application	Core Strengths	Weaknesses
MS Projects	▪ Scheduling ▪ Cost effective ▪ Easy to use ▪ Most widely used in industry	▪ Cost management ▪ Risk management ▪ BIM and drawing interface ▪ Field management
Primavera	▪ Scheduling ▪ Resource management ▪ Portfolio management ▪ Risk analyses	▪ Cost management ▪ Workflow management ▪ BIM and drawing interface
CCS	▪ Cost management ▪ Scheduling ▪ Earned value integrator	▪ Portfolio management ▪ Document management ▪ BIM and drawing interface
Aconex	▪ Document management ▪ Workflow management ▪ Field management ▪ BIM and drawing interface	▪ Scheduling ▪ Cost management
Trimble	▪ Cost management ▪ Document management ▪ Workflow management ▪ Field management ▪ BIM and drawing interface	▪ Scheduling ▪ Portfolio management

Table 3 Strengths and Weaknesses of Common Project Management Software in Construction and Engineering
Note. Adapted from "Smart Project Management Information Systems (SPMIS) for Engineering Projects – Project Performance Monitoring & Reporting," by J. van Besouw & T. Bond-Barnard, 2021, University of Pretoria. Copyright 2021 by the authors.

The table above categorizes the strengths of each software in areas such as scheduling, cost management, resource management, workflow integration, and document handling. For

instance, MS Projects is noted for its simplicity, cost-effectiveness, and widespread adoption in the industry, with its primary strength being scheduling. However, its weaknesses include limited integration for cost management, risk management, and Building Information Modelling (BIM).

Primavera is a comprehensive project management software suite developed by Oracle, specifically designed for managing large-scale, complex projects. Widely used in industries like construction, engineering, and energy, Primavera provides advanced capabilities for scheduling, resource management, risk analysis, and project tracking. The software enables project managers to plan, monitor, and control every aspect of a project, from timelines and costs to resources and risks.

Microsoft Project (MS Project) is a project management software developed by Microsoft that helps project managers plan, schedule, and manage projects of various sizes. Widely used across industries, MS Project is known for its user-friendly interface and robust scheduling and resource management features. It is especially popular in industries like construction, IT, engineering, and manufacturing for organizing tasks, managing resources, and tracking project progress.

Primavera stands out for its capabilities in scheduling, resource management, portfolio management, and risk analysis. Despite these advantages, it shows weaknesses in areas such as cost management, workflow integration, and the handling of BIM interfaces, which can pose challenges in projects requiring extensive collaboration or visualization. (Van Besouw & Bond-Barnard, 2021).

The paper highlights Construction Computer Software (CCS) as a robust tool in project management, particularly excelling in cost management and scheduling. Its advanced financial control and cost estimation capabilities enable project managers to effectively monitor expenses and profitability, while its scheduling features support detailed timeline planning and management. Additionally, CCS integrates earned value management, allowing for accurate performance tracking against project baselines. The inclusion of BIM and drawing interfaces further enhances collaboration by facilitating design visualization and real-time project updates. However, the paper notes that CCS has limitations in portfolio and document management, making it less suitable for multi-project environments or projects requiring extensive documentation handling. (Van Besouw & Bond-Barnard, 2021).

Aconex is highlighted as a leading tool for document and workflow management, offering exceptional capabilities in handling and distributing project documents while ensuring version control and accessibility for all stakeholders. Its workflow management features streamline processes, enabling users to create and track task progress efficiently. Aconex also excels in real-time communication, fostering transparency and improving accountability among project participants. Furthermore, its integration with BIM enhances collaborative efforts by supporting markup and review of 3D models, making it an invaluable tool for projects requiring multidisciplinary coordination and precision. (Van Besouw & Bond-Barnard, 2021).

Trimble is recognized as a versatile tool in PMIS, offering robust functionalities in cost and document management. Its cost management features enable precise budget tracking and financial control, while its document management capabilities ensure seamless data flow across project teams. Additionally, Trimble enhances workflow optimization by integrating field management with task tracking and document sharing. The inclusion of a BIM interface and drawing markup features further supports project visualization and collaboration. However, the paper highlights limitations in Trimble's scheduling and portfolio management capabilities compared to tools like Primavera. This comparison underscores the variability in PMIS tools,

with CCS and Primavera excelling in scheduling and cost management, while Aconex and Trimble focus on document and workflow management. The research emphasizes the need for organizations to select complementary tools based on specific project needs, as no single software solution fully addresses all project requirements. Combining the strengths of different tools can create a robust project management ecosystem tailored to modern challenges.

This comparison underscores the diversity of capabilities offered by different PMIS tools, emphasizing the importance of selecting software that aligns with the specific needs of a project. It also highlights the trade-offs between specialized functionalities and the integration of broader project management capabilities, reflecting the need for strategic software selection and possible integration of multiple tools to address project complexities. (Van Besouw & Bond-Barnard, 2021).

According to the interviews conducted by Van Besouw and Bond-Barnard (2021) using a semi-structured method, thirteen senior professionals from the South African engineering and construction sector were purposively selected. These participants, holding roles such as project managers, project controllers, and directors, were involved in managing large, complex projects across industries like mining, energy, water treatment, and infrastructure. The interviews, comprising 25 core questions with additional follow-ups, aimed to explore the use, functionality, and integration challenges of Project Management Information Systems (PMIS) within their organizations. The results of this qualitative study informed the development of the project performance factors represented in the figure below, which illustrate key areas impacted by PMIS integration (Van Besouw & Bond-Barnard, 2021).

Inter-view	Project Cost Management	Time Sheets	Project Resource Management & Histograms	Document Management & Workflow Management	Project Schedule Management	Drawing & BIM Software
1	MS Excel	None	None	Windows Server Based	MS Project	None
2	PPO	PPO	None	PPO	MS Project	
3	IFS	IFS	Primavera	Aconex & M-Files	Primavera	Autodesk Revit
4	Great Plains	Primavera	Primavera	EB, Google Drive	Primavera	
5	Cispro	SDK	MS Project	DR Pro, Windows, done manually	MS Project, CCS Candy	Autodesk, Smart Plant, Aveva
6	Envisage	Clock o Fi	Asana	EB	MS Project	
7	Prism, SAP, Excel	Saeco	None	Standard Windows Server	MS Project	Autodesk, Pro-Engineer
8	CCS Candy	None	None	Solidworks	MS Projects	
9	MS Excel, Pastel & V6	MS Excel	CCS Candy	Wownet, MS Team Member	MS Projects, CCS Candy	Bentley/Navisworks
10&11	BST Global, Revit, Builder	BST	MS Excel	Share Point, BIM 360	MS Projects	
12	SAP, Trimble, CCS Candy	SAP bolt on, custom built tool	SAP bolt on, custom built tool	Livelink	Primavera & MS Projects	Solidworks/Revit
13	CCS Candy, BuildSmart	SAS (custom in house system)	SAS (custom in house system)	Docwise	CCS Candy	

*MS=Microsoft PPO=Project Portfolio Office CCS=Construction Computer Software

Figure 3 Distribution of Software Tools by Project Management Functionality

Note. Adapted from "Smart Project Management Information Systems (SPMIS) for Engineering Projects – Project Performance Monitoring & Reporting," by J. van Besouw & T. Bond-Barnard, 2021, University of Pretoria. Copyright 2021 by the authors.

The figure, adapted from Van Besouw and Bond-Barnard (2021), summarizes insights from interviews with senior professionals, highlighting the utilization of different software for tasks such as project cost management, scheduling, document workflow management, and Building Information Modelling (BIM). The figure underscores the diversity of tools used in practice, ranging from industry-standard solutions like MS Projects, Primavera, and Autodesk Revit to custom-built and in-house systems tailored to organizational needs.

This data reflects the fragmentation and variability in PMIS usage across organizations, even within the same sector. The reliance on multiple software applications indicates the need for integration to enhance interoperability, streamline workflows, and reduce redundancies.

By highlighting the variety of tools in use and their respective roles, the figure provides a practical foundation for understanding how PMIS integration can address gaps in functionality and foster collaboration across diverse project environments. The insights from these interviews highlighted significant barriers to PMIS integration, particularly in handling fragmented data across multiple systems, and underscored the need for more cohesive, intelligent PMIS solutions to support efficient project monitoring and reporting.

4. DISCUSSION

The primary objective of this research was to explore how Project Management Information Systems (PMIS) can be enhanced through integration with advanced tools and technologies, such as Building Information Modelling (BIM), Supply Chain Management (SCM) systems, Decision Support Systems (DSS), and Smart PMIS (SPMIS). This study aimed to address gaps in PMIS functionality, particularly focusing on improving project efficiency, fostering collaboration, and supporting informed decision-making in complex project environments.

The Results Chapter revealed several critical insights into the strengths and limitations of various PMIS tools, including ERP systems, Microsoft Project, CCS, Trimble and Primavera. The findings demonstrated that while these tools excel in specific functions—such as cost management, scheduling, and workflow optimization—they often face challenges in achieving seamless integration and interoperability.

These findings highlight significant gaps in how PMIS tools currently address integration challenges. The research also underscores the transformative potential of emerging technologies, such as BIM integration, to bridge these gaps. For instance, BIM-based PMIS was shown to enhance collaboration and lifecycle management by providing a centralized platform for real-time data sharing and decision-making. (Ma et al., 2018).

By connecting these findings to the research questions outlined in the introduction, this study demonstrates how integrating advanced systems and technologies into PMIS can mitigate issues such as data fragmentation, limited interoperability, and inefficiencies in collaboration. The results provide a solid foundation for understanding how PMIS can evolve to meet the demands of modern, complex projects, particularly in industries such as construction and engineering.

4.1 Integration Challenges and Opportunities:

The findings of this study reinforce the value of PMIS in enhancing project efficiency, particularly within the construction industry, which is known for its fragmented structure and complex project environments. The data underscore PMIS's role in advancing collaboration, data management, cost control, aligning with extensive literature that positions PMIS as a solution to longstanding project coordination challenges. By supporting integrated workflows and real-time data access, PMIS fosters more cohesive communication and minimizes inefficiencies within project supply chains (Mehrjerdi, 2009; Kamath & Roy, 2007).

ERP Systems

One of the most significant opportunities offered by ERP systems is their capacity for data flow across project management modules. By integrating systems such as Building Information Modelling (BIM) and Supply Chain Management (SCM), ERP frameworks enable real-time data exchange, fostering alignment among project stakeholders. This integration provides organizations with the ability to adapt to changing project conditions dynamically, ensuring that project managers have consistent access to updated information for making timely, informed decisions (Zhao & Yin, 2006).

ERP systems further enhance decision-making by supporting critical project functions, including scheduling, cost control, and resource allocation. Through tools like Enterprise Application Integration (EAI), ERP systems harmonize the Work Breakdown Structure (WBS)

and other planning mechanisms, eliminating redundancy and enabling the efficient transfer of optimized project plans. This creates a unified platform where project teams can manage data effectively, reduce errors, and improve overall productivity (Tulupov, 2020).

Despite these strengths, ERP systems face notable challenges in implementation. Integration complexity is one of the most significant barriers, as many ERP systems require extensive customization to ensure compatibility with existing tools like PM software or BIM systems. Differences in vendor-specific architectures and data standards often result in fragmented information systems, hindering seamless data exchange and limiting the system's potential to support real-time collaboration. Without smooth data flow, project managers may struggle to maintain alignment among teams, leading to inefficiencies and delays. (Tulupov, 2020).

Web-based Project Management Systems (WPMS)

One of the most significant opportunities WPMS offers is cost efficiency and flexibility through deployment via Application Service Providers (ASPs). By allowing organizations to rent or lease software, WPMS eliminates the need for costly installations and lowers entry barriers for smaller firms. This creates a centralized data hub accessible to geographically dispersed teams without requiring extensive IT infrastructure. The ability to provide a unified platform for information sharing enhances coordination and ensures that project teams have consistent access to up-to-date data. (Nitithamyong & Skibniewski, 2003).

Another key advantage is real-time collaboration across project stages. WPMS supports dynamic, live data sharing, enabling project teams to make immediate updates and decisions. This functionality is particularly valuable for multi-stakeholder projects where timely communication is essential to maintaining progress and mitigating risks. The integration of WPMS with PMIS enhances decision-making by ensuring that all project participants are aligned and working with the most current information. (Nitithamyong & Skibniewski, 2003).

However, the adoption of WPMS is not without its challenges. A major limitation identified by this research is reliance on stable internet connectivity. Projects in remote areas or regions with unreliable online access may experience significant disruptions in communication and data sharing, which can hinder project timelines and stakeholder coordination. Ensuring consistent connectivity remains a critical concern for fully leveraging WPMS capabilities. (Nitithamyong & Skibniewski, 2003).

Another critical challenge is cybersecurity risks. Storing sensitive project data on web-based platforms exposes organizations to potential data breaches and unauthorized access. This research emphasizes that robust security measures, such as encryption and access controls, are essential to safeguarding the integrity and confidentiality of project data (Nitithamyong & Skibniewski, 2003).

Supply Chain Management (SCM) Integration

key opportunity of PMIS-SCM integration is its ability to enhance real-time data flow across the supply chain. Automated data capture and feedback loops, such as 3D laser scanning synchronized with project schedules, ensure that project managers receive accurate and timely updates. (Braglia & Frosolini,2014). This promotes informed decision-making, allowing teams to respond proactively to changes and ensure that project timelines and budgets remain on track. Reliable, up-to-date information is critical for maintaining alignment among stakeholders and reducing uncertainties during project execution**.**

Additionally, PMIS-SCM integration fosters cost and error reduction by standardizing processes and ensuring data accuracy. This research highlights how standardization minimizes redundancies, reduces manual data entry errors, and streamlines workflows, which are particularly important in industries like construction that depend on complex supply chains. Enhanced collaboration between supply chain participants also reduces unnecessary inventory and improves resource allocation, contributing to greater overall productivity.

Despite its potential, PMIS-SCM integration is not without challenges. Interoperability issues remain a significant barrier, as diverse PMIS platforms often lack universal data standards, requiring substantial customization and manual intervention. The lack of seamless data exchange can hinder the system's ability to deliver real-time insights and accurate information, undermining the efficiency of supply chain operations.

Furthermore, resistance to change from stakeholders accustomed to traditional methods poses an additional barrier to successful implementation. This cultural shift requires significant organizational effort to encourage adoption and ensure effective utilization of the system.

Decision Support Systems (DSS) Integration

One of the most impactful contributions of DSS integration is its ability to enhance decision-making through advanced modelling techniques. Tools like sensitivity analysis and scenario simulations provide project managers with the means to evaluate multiple outcomes and choose the most effective strategies. This capability ensures that decisions are not only informed but also optimized for the specific challenges of dynamic and uncertain project environments (Hahn & Kuhn, 2012).

Another critical advantage is the role DSS plays in risk and resource optimization. By consolidating data from various project areas—such as cost, schedule, and resource allocation—DSS tools like @Risk and Crystal Ball (Oracle) enable managers to identify critical risk variables and allocate resources more effectively. This ensures that project plans are robust and adaptable, supporting proactive decision-making and minimizing potential disruptions (Metzger et al., 1998; Seňová et al., 2023).

However, despite these advantages, DSS integration presents several challenges. The complexity of implementation requires significant technical expertise and alignment of organizational processes. Without proper planning and skilled personnel, organizations risk operational disruptions and underutilization of the system.

Smart Project Management Information Systems (SPMIS)

This research demonstrates that Smart Project Management Information Systems (SPMIS) represent a transformative evolution in project management, leveraging advanced technologies like artificial intelligence (AI) and machine learning (ML) to enhance efficiency and decision-making. The integration of SPMIS into project workflows offers substantial opportunities, particularly in areas of data-driven collaboration, real-time insights, and strategic planning (Van Besouw & Bond-Barnard, 2021).

A key opportunity lies in SPMIS's ability to consolidate and automate data processes. By integrating data from diverse sources into a centralized platform, SPMIS ensures accurate and consistent data flow, enabling project managers to monitor performance effectively and identify patterns through predictive analytics. This capability significantly enhances project monitoring, allowing teams to address potential risks proactively and allocate resources efficiently (Jaafari & Manivong, 1998; Van Besouw & Bond-Barnard, 2021).

Another major strength of SPMIS is its support for real-time decision-making. By consolidating data on costs, schedules, and risks, these systems provide actionable insights that allow project managers to make informed decisions swiftly. The dynamic nature of SPMIS helps organizations adapt to evolving project conditions, ensuring strategic resource allocation and reducing delays caused by outdated or fragmented information (Van Besouw & Bond-Barnard, 2021).

User adoption is another critical concern. The advanced features of SPMIS require specialized training for effective utilization. Without adequate education, users may resist transitioning from traditional workflows, leading to underutilization of the system and a failure to realize its full potential (Van Besouw & Bond-Barnard, 2021).

Building Information Modelling (BIM)

The key opportunity of BIM lies in BIM's support for advanced decision-making capabilities and workflow optimization. Through 4D (time) and 5D (cost) modelling, BIM enables project managers to simulate scenarios, optimize resource allocation, and evaluate potential outcomes before implementation. This real-time insight into project dynamics empowers project managers to make precise and data-driven decisions, ensuring adaptability to evolving project requirements (Hahn & Kuhn, 2012).

The high costs of implementation and technical requirements are another challenge associated with adopting BIM. The need for specialized software, infrastructure, and skilled personnel poses barriers, particularly for smaller organizations or those with limited resources. Additionally, resistance to change within teams accustomed to traditional workflows can further slowdown BIM adoption, undermining its potential benefits (Ma et al., 2018).

This research asserts that the true success of BIM in project management lies in prioritizing seamless interoperability and consistent data flow. These factors are essential for enabling the efficient exchange of information across systems and ensuring that project managers can make data-driven decisions. By focusing on these elements, organizations can leverage BIM to its full potential, creating a cohesive and effective project management ecosystem. The combination of robust data flow and decision-making support establishes BIM as a foundational tool for addressing the complexities of modern project environments.

4.2 Software-Specific Reflections on Integration

Microsoft Project (MS Project):

As identified in the article by Van Besouw and Bond-Barnard (2021), one of the main barriers in PMIS integration is fragmented data across systems, which complicates project monitoring and reporting. Microsoft Project is particularly advantageous due to its extensive scheduling and timeline management features, allowing project managers to track tasks, assign resources, and establish clear dependencies in a streamlined manner (Van Besouw & Bond-Barnard, 2021).

Despite its popularity, Microsoft Project faces challenges in fully integrating with other project functions critical for construction, such as cost management, document handling, and field management. The study highlights that while Microsoft Project excels in scheduling, its integration with cost management and risk analysis is limited, necessitating additional tools for a comprehensive PMIS solution. For instance, organizations often resort to manually exporting scheduling data from Microsoft Project into other systems to manage project costs or track real-

time project changes. This reliance on manual integration increases the potential for data entry errors and delays in project reporting.

Moreover, Microsoft Project's limited compatibility with certain Building Information Modelling (BIM) applications, as mentioned in the research, restricts its use in projects where 3D models and real-time field updates are critical. Although it offers some interoperability with other Microsoft tools like SharePoint and Teams, full integration with non-Microsoft systems remains challenging, highlighting a need for cohesive and intelligent PMIS solutions that Microsoft Project alone cannot address. Thus, while Microsoft Project supports foundational scheduling needs effectively, its limited integration capability underscores the need for supplemental tools or systems to achieve holistic project performance monitoring and reporting (Van Besouw & Bond-Barnard, 2021).

Primavera:

Unlike Microsoft Project, Primavera is designed to handle large-scale, complex projects and offers advanced features suited to the detailed needs of construction project management.

Primavera is better equipped than Microsoft Project to address the integration challenges highlighted in the study, particularly through its ability to consolidate data from diverse sources and manage it centrally. Primavera supports integration with various third-party applications, including ERP systems and Building Information Modelling (BIM) software, which helps reduce data fragmentation. This interoperability enables project teams to access and analyze real-time data across multiple dimensions—scheduling, costs, resources, and risks—streamlining project monitoring and reporting. This centralization addresses one of the primary integration barriers by reducing the need for manual data transfers between disparate systems, thereby minimizing data entry errors and improving overall project transparency. (Van Besouw & Bond-Barnard, 2021).

Moreover, Primavera's risk management capabilities are more advanced, allowing for comprehensive risk analysis that is directly integrated with scheduling and cost management. This integration makes Primavera especially useful for construction projects where risk mitigation is critical to project success. Primavera's system also offers enhanced reporting features that facilitate real-time insights into project performance metrics, making it easier for project managers to track progress against predefined benchmarks and adjust plans proactively. (Van Besouw & Bond-Barnard, 2021).

4.3 Integration Reflections

ERP (Enterprise Resource Planning) integration with PMIS stands out as the most important and effective integration due to its ability to centralize project functions, improve data flow, and provide a cohesive framework for managing complex projects. While other systems like BIM and SPMIS offer specific advantages, ERP integration delivers unparalleled benefits by addressing the core challenges of fragmented data, inefficient workflows, and lack of comprehensive oversight.

1. Centralized Project Management Framework

ERP systems excel at integrating multiple project management functions—such as scheduling, cost control, resource allocation, and risk management—into a unified platform. This integration eliminates silos by consolidating data from various departments and modules, providing project managers with a **holistic view of project performance**. For industries like

construction and engineering, where cross-functional coordination is essential, ERP ensures seamless alignment across all project activities (Zhao & Yin, 2006).

2. Enhanced Data Flow Across Systems

ERP integration ensures **real-time data flow**, which is critical for informed decision-making. By linking PMIS with other modules like Building Information Modelling (BIM) and Supply Chain Management (SCM), ERP enables the continuous exchange of accurate and up-to-date information. This ensures that all stakeholders work with consistent data, reducing redundancies, miscommunication, and delays. The ability to maintain smooth data flow makes ERP integration invaluable for managing complex, dynamic projects (Tulupov, 2020).

3. Comprehensive Resource Management

ERP systems are particularly effective in managing resources—both human and material—through detailed tracking and forecasting tools. Integrated PMIS functions, such as Work Breakdown Structure (WBS) planning, harmonize with ERP's enterprise-level capabilities, allowing for precise resource allocation and cost optimization. This unified approach ensures that project objectives align with organizational goals, enhancing both efficiency and accountability.

4. Scalability for Large and Complex Projects

ERP integration is highly scalable, making it ideal for large-scale and multi-phase projects. By creating a cohesive enterprise-wide information system, ERP ensures that PMIS can adapt to evolving project demands. Its compatibility with advanced tools like SPMIS and BIM further enhances its scalability, allowing organizations to incorporate predictive analytics, lifecycle management, and real-time visualization within a single, integrated ecosystem.

5. Improved Collaboration and Transparency

ERP systems enhance collaboration by breaking down barriers between departments and stakeholders. Integrated workflows ensure that information is accessible across teams, promoting transparency and reducing bottlenecks. For instance, ERP's integration with SCM systems enables better coordination in supply chain operations, while its compatibility with BIM ensures that design, construction, and operational teams remain aligned throughout the project lifecycle (Zhao & Yin, 2006; Tulupov, 2020).

5. CONCLUSION

In an era of rapid technological advancement and increasing project complexity, the field of project management is undergoing significant transformation. Modern projects, particularly within industries like architecture, engineering, and construction (AEC), demand a high level of precision, collaboration, and adaptability to succeed. Traditional approaches to managing projects often fall short in addressing challenges such as fragmented data, inefficient workflows, and delayed decision-making. These limitations have driven the adoption of innovative solutions that leverage technology to enhance efficiency, foster collaboration, and improve decision-making across the project lifecycle.

By employing a systematic literature review (using the PRISMA framework) and incorporating qualitative data from relevant case studies, tables, and figures, the research systematically identified challenges and opportunities associated with PMIS integration.

This thesis has examined these evolving dynamics, focusing on the integration of advanced tools and systems into Project Management Information Systems (PMIS). Specifically, it highlights the role of cutting-edge technologies such as Smart Project Management Information Systems (SPMIS) and Building Information Modelling (BIM), as well as the benefits of integrating various systems like supply chain management, decision support systems, and project management software.

The research highlights the crucial role that Project Management Information Systems (PMIS) integrations play in enhancing project management across multiple dimensions, particularly in improving efficiency, communication, and data flow. The main types of software integrations examined include collaboration tools, supply chain management systems, decision support systems, and Integration of SPMIS for Enhanced Project Management Efficiency. Each integration brings unique advantages to project management, as summarized below:

1. **Collaboration and Communication Integration**

Integrating communication and collaboration tools, such as Web-based Project Management Systems (WPMS), into PMIS fosters real-time data flow and streamlines document management. This integration reduces communication bottlenecks by facilitating document sharing and real-time updates across stakeholders. By enhancing collaborative processes, these tools also mitigate delays in data exchange and improve alignment among project participants, especially in fragmented project structures within the Architecture, Engineering, and Construction (AEC) industry (Dossick & Sakagami, 2008).

2. **Supply Chain Management (SCM) Integration**

PMIS integration with Supply Chain Management (SCM) systems enables efficient coordination of materials, finances, and information throughout the supply chain. Standardization in SCM integration minimizes errors and costs by enhancing data consistency and reducing manual data entry requirements. This interoperability across systems also supports faster response times to project demands, leading to improved overall productivity and resource management (Mehrjerdi, 2009).

3. **Decision Support Systems (DSS) Integration**

Integrating Decision Support Systems (DSS) within PMIS provides project managers with tools for optimizing scheduling, resource allocation, and risk management. DSS offers quantitative modelling capabilities, such as scenario analysis, which enhances decision-making

under uncertainty. This integration is particularly beneficial for managing complex projects, as it supports dynamic resource optimization and aids in adapting to project changes in real-time (Hans et al., 2007).

4. Project Management Software Integration

Integrating specific project management software, such as Microsoft Project and Primavera, centralizes project functions, including scheduling, cost control, and resource management. These integrations allow for a more cohesive view of project progress, with ERP systems, in particular, unifying various project functions on a single platform. Tools like Primavera are well-suited for large-scale projects, offering advanced capabilities in risk management and reporting, which are essential for maintaining project transparency and accountability (Tulupov, 2020).

5. ERP systems

ERP integration provides a robust framework for consolidating enterprise-wide data and ensuring seamless interaction between resource management and project-specific functions. By centralizing core operations such as scheduling, budgeting, and resource allocation, ERP systems eliminate silos and enhance overall project efficiency. Their ability to integrate with modules like PM software and SCM enables real-time data flow and adaptability, supporting informed decision-making and strategic planning. This comprehensive functionality positions ERP as a key component in achieving streamlined and cohesive project management.

6. Integration of SPMIS for Enhanced Project Management Efficiency

Building on the findings of this research, the integration of Smart Project Management Information Systems (SPMIS) emerges as a transformative opportunity in addressing the challenges of modern project environments. Recent advancements in big data technology and artificial intelligence have enabled SPMIS to offer real-time data consolidation, advanced analytics, and intuitive reporting capabilities. These systems automate the collection and interpretation of data from diverse sources, providing project managers with actionable insights that enhance decision-making precision and strategic planning. By addressing the limitations of traditional PMIS, such as fragmented data and labor-intensive processes, SPMIS facilitates seamless collaboration across stakeholders, reduces project risks, and optimizes resource allocation. The adoption of such intelligent, cloud-based platforms not only improves operational efficiency but also positions organizations for competitive advantages in increasingly dynamic and complex project landscapes. This integration underscores the necessity of embracing intelligent technologies to fully realize the potential of PMIS in supporting proactive and data-driven project management. (Van Besouw & Bond-Barnard, 2021).

7. BIM and Its Integration with PMIS

Similarly, BIM offers a model-based cooperative approach, enabling centralized data management, workflow optimization, and enhanced collaboration across multidisciplinary teams throughout the project lifecycle. The integration of BIM into PMIS facilitates seamless data sharing and visualization, improving interoperability, decision-making, and resource allocation. By consolidating real-time project insights into a unified platform, this synergy reduces risks, enhances accountability, and ensures efficient resource utilization. Ultimately, the combined use of SPMIS and BIM represents a paradigm shift, positioning organizations to better navigate the complexities of modern projects while achieving operational excellence and stakeholder satisfaction. (Ma et al., 2018).

The findings from this research provide valuable insights for industry practitioners, particularly project managers in sectors like construction, engineering, and infrastructure, where Project Management Information Systems (PMIS) play a pivotal role.

This research concludes that **ERP integration with PMIS is the most impactful and effective** for improving project management efficiency. ERP's ability to centralize diverse functions, ensure **real-time data flow**, and support scalable, enterprise-wide frameworks positions it as the cornerstone of modern project management systems. Its compatibility with other modules like BIM and SCM further enhances its versatility, making it an indispensable tool for managing complex, large-scale projects. By prioritizing ERP integration, organizations can achieve a cohesive, transparent, and data-driven project management ecosystem that delivers both strategic and operational excellence.

Limitations and Future Directions for PMIS Integration Research

While this research provides a comprehensive overview of PMIS integrations and their benefits, several limitations were encountered that may affect the generalizability and depth of the findings:

This study focused primarily on widely-used PMIS integrations within established categories, such as SCM, DSS, and ERP. However, due to the rapidly evolving landscape of project management technology, many emerging or niche software integrations were not covered. This limitation may exclude certain industry-specific integrations that could yield additional insights into PMIS functionality and impact.

This study's systematic review approach relied on published literature and existing research, which may be subject to publication bias. Relevant findings from unpublished studies, industry reports, or proprietary sources were not included, potentially skewing the results toward commonly studied PMIS integrations. This reliance on secondary data restricts the diversity of perspectives included in the analysis.

While PMIS applications were studied across multiple industries, the findings may not fully reflect sector-specific challenges. The construction industry, for instance, has unique project management requirements compared to fields like IT or healthcare, where PMIS usage and integration needs differ. This variability may limit the applicability of certain conclusions to specific project types or industries.

The study primarily examined short-term outcomes of PMIS integrations rather than their long-term impact on project success and sustainability. Without longitudinal data, it is challenging to assess how these integrations perform over the lifecycle of a project or adapt to ongoing changes in project demands, technology, and team composition.

Future research can expand on this study by exploring emerging technologies, particularly the potential integration of Artificial Intelligence (AI) and Machine Learning (ML) with PMIS. Currently, most PMIS systems lack integration with AI and ML tools, which could transform project management by enabling predictive analytics, automated decision-making, and advanced risk assessments. Incorporating AI and ML could allow PMIS to provide real-time insights, anticipate project challenges, and optimize resource allocation more effectively.

Additionally, future studies could examine the long-term impacts of these integrations across diverse industries, assess user adoption challenges, and investigate the adaptability of PMIS as

technology advances. This research would provide valuable insights into the evolving landscape of project management technology, ensuring that PMIS continues to meet the complex needs of modern projects.

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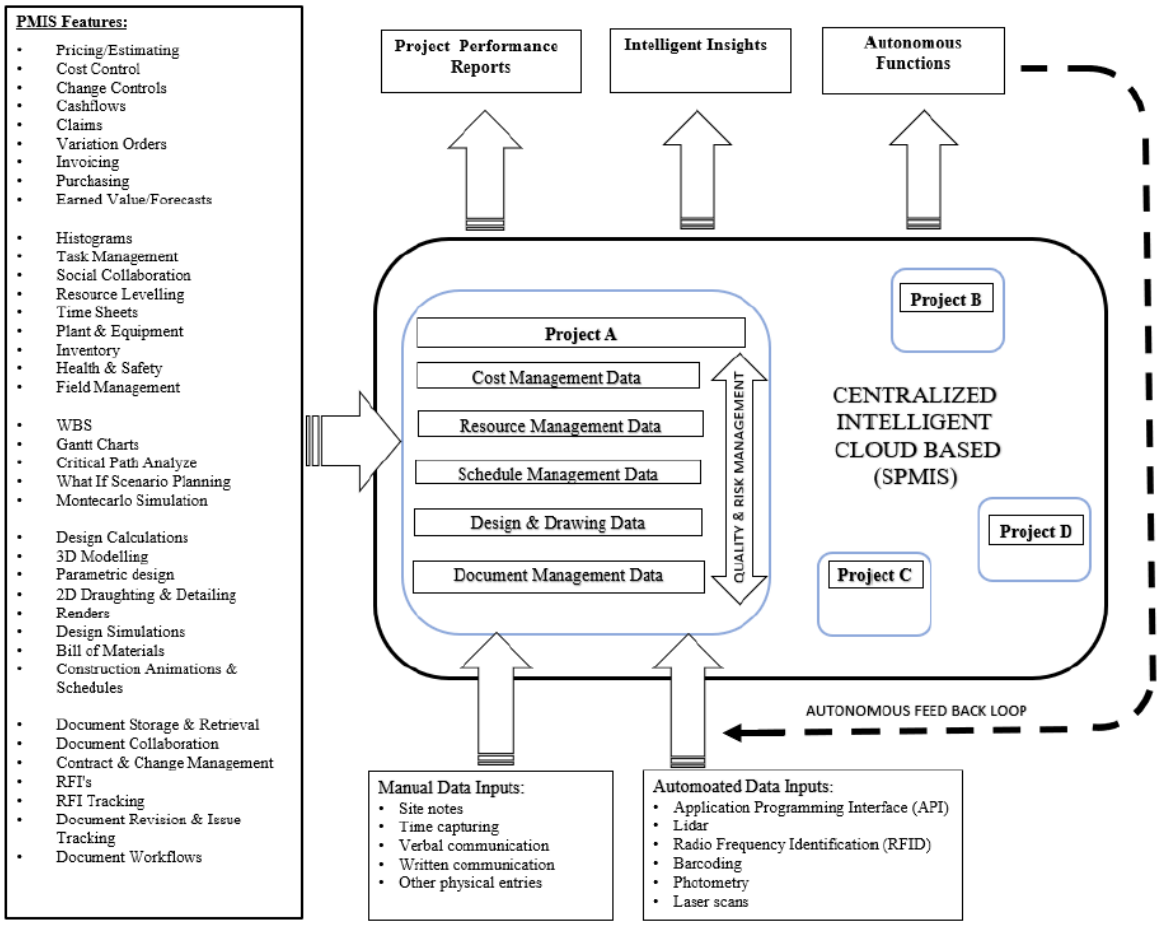
7.List of figures and tables

Appendix A



Note. Adapted from "Smart Project Management Information Systems (SPMIS) for Engineering Projects – Project Performance Monitoring & Reporting," by J. van Besouw & T. Bond-Barnard, 2021, University of Pretoria. Copyright 2021 by the authors.