

عنوان البحث

" دراسة تطبيقية على أثر التحول الرقمي على إدارة
المشاريع الهندسية "

**“Applied Study on Impact of Digital Transformation on
Engineering Project Management”**

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العام الدراسي: 2024

Abstract

This research explores the profound effects of digital transformation on managing engineering projects. Digital transformation involves incorporating digital technologies across all organizational aspects, fundamentally altering the approach to project management, execution, and delivery. Within the engineering sector, this transformation encompasses the adoption of advanced tools and methods, including Building Information Modeling (BIM), the Internet of Things (IoT), Artificial Intelligence (AI), and cloud computing, which collectively enhance project efficiency, collaboration, and results.

Key objectives:

- Evaluate the adoption of digital transformation in engineering project management.
- Identify the digital tools that are driving change in project management techniques.
- Assess the impact on project performance (time, cost, and risk).
- Explore barriers to digital transformation adoption.
- Create recommendations for effective digital integration.

This study will use a mixed methods approach, beginning with a literature review to establish a theoretical foundation. Surveys will collect quantitative data from project managers, while in-depth interviews with industry experts yield qualitative insights. Case studies of successful digital tool implementations will demonstrate best practices.

The research aims to identify effective digital tools, common challenges, and provide practical solutions for successfully integrating digital technologies into engineering project management.

Acknowledgement

I would like to express my sincere thanks to all those who helped and guided me throughout the development of this research on the "Applied Study on Impact of Digital Transformation on Engineering Project Management". Without their significant help, this work could not have been completed.

First and foremost, I would like to express my sincere gratitude to my academic advisor, Dr. Asma Abuanzeh, for their continuous support, intelligent advice, and critical input throughout this study process. Their knowledge and support helped shape the direction and quality of this research. I am deeply grateful to the instructors and staff of Administration College at Midocean University for creating an excellent academic environment and providing access to critical resources that aided my studies.

My sincere thanks go to the professionals and industry experts who kindly offered their time, knowledge, and experience during the interviews and surveys. Their practical ideas and real-world insights greatly increased the breadth and significance of this research.

I would also like to thank my friends and colleagues for their camaraderie, and collaborative approach and for being a constant source of motivation and inspiration. Their honest conversations and criticism helped develop my research ideas and approaches.

Thank you, family and friends, for your constant support, understanding, and encouragement throughout this journey. Your belief in my abilities and unwavering encouragement has been my greatest source of strength and enthusiasm.

This research is a collaborative effort and I am grateful to everyone who has helped in any way. Thank you for your wonderful support and encouragement.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Digital transformation, defined as the use and integration of digital technology across multiple domains, has fundamentally changed industries globally. In engineering project management, digital transformation involves leveraging advanced technologies like artificial intelligence (AI), the Internet of Things (IoT), big data analytics, cloud computing, and building information modeling (BIM) to enhance project planning, execution, and process monitoring. Given the sector's reputation for complex, large-scale projects, these technological advancements contribute to greater efficiency, reduced costs, and improved project outcomes (Fitzgerald et al., 2014).

The advancement of digital technology has transformed project management practices, especially in engineering, where projects frequently involve substantial complexity, high costs, and extended timelines (Ozorhon and Oral, 2017). Traditionally, construction project management faced challenges such as fragmented communication, disjointed workflows, and reliance on manual processes, contributing to inefficiencies and delays. These inefficiencies are often exacerbated by perception gaps between stakeholders, leading to further project overruns and missed deadlines (Milind Mehta et al., 2022). The introduction of digital tools, however, is driving a shift towards more streamlined, data-driven approaches. For instance, BIM allows for a collaborative process where various stakeholders can visualize and manipulate a project's digital twin in real-time, leading to more accurate planning and reduced errors (Bilal et al., 2016).

On the other hand, the arrival of digital transformation has created new chances for efficiency in project management. Engineering businesses can increase decision-making

capabilities, improve data accuracy, and streamline project workflows by leveraging digital tools and technologies (Whyte et al., 2016). Digital transformation also aids in optimizing resource allocation and improving risk management in projects. Utilizing technologies such as artificial intelligence and machine learning, project managers can analyze historical data to forecast potential risks, allowing for more strategic and proactive decision-making (Zhang et al., 2023).

1.2.Rationale

The rationale for the research stems from the growing need for engineering companies to adopt digital transformation strategies to stay competitive in a rapidly changing market. The rapid pace of technological advancement has created a significant challenge for engineering firms: how to adapt traditional project management practices to incorporate digital transformation. While digital tools such as BIM, AI, and IoT can enhance project outcomes, the adoption and integration of these technologies often face several barriers. These include the high costs associated with implementing new systems, resistance to change among staff, and a lack of digital skills (Pan & Zhang, 2022).

For the engineering sector (Golini et al., 2015). Engineering firms must understand how the digital transition affects project management to effectively manage these changes and take full advantage of digital technologies.

Project efficiency, risk management, and stakeholder participation can all be greatly enhanced through digital transformation (Lu et al., 2020). But it also brings difficulties, including reluctance to adapt, the need for upskilling, and cyber security issues.

Without a thorough grasp of digital transformation's impact, many firms risk falling behind in an increasingly competitive market. This study seeks to bridge these gaps by assessing how digital transformation influences engineering project management, identifying the key tools and technologies driving these changes, and exploring both the benefits and challenges associated with

adopting digital transformation in engineering projects.

1.2 Research Questions and Hypotheses

1. Research Questions

- i. How does digital transformation affect the planning and implementation of engineering projects?
- ii. What are the main digital tools and technologies affecting project management in engineering?
- iii. What are the advantages and disadvantages of digital transformation in engineering project management?

2. Research Hypotheses

- i. **H1:** Digital transformation increases the effectiveness and efficiency of engineering project planning and execution.
- ii. **H2:** Using digital tools and technologies improves collaboration and communication between project stakeholders.
- iii. **H3:** Despite its benefits, digital transformation comes with challenges, such as reluctance to change and significant implementation costs.
- iv. **H4:** Digital Transformation Impacts Risk Management Practices on Engineering Project Management in Positive Ways.
- v. **H5:** Engineering firms that implement digital transformation techniques achieved improved project results in contrast to those that did not.

1.3 Scope and Limitations of the Study

This study focuses on how engineering project management is affected by digital transformation. Adopting digital tools and platforms, modifying project workflows, and

influencing project outcomes are important aspects of digital transformation. These tools will be considered in several engineering industries like manufacturing, infrastructure development, and construction. A comprehensive study of the global impacts of digital transformation will look at case studies and examples from both industrialized and developing countries. It is constrained by the accessibility of up-to-date data and the fast-evolving landscape of digital technology.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of Digital Transformation

Digital transformation refers to the complete incorporation of digital technologies across all areas of a business or industry, radically changing the way operations are conducted and value delivered to clients (Vial, 2019). To fully leverage digital technologies, this process involves, in addition to automating or digitizing current processes, also rethinking and redesigning business models, procedures, and organizational structures (Henriette et al., 2015). Embracing emerging technologies, enhancing digital competencies, and fostering a digital-centric culture in companies are essential elements of digital transformation (Westerman et al., 2014).

Digital transformation extends beyond merely adopting new technologies; it involves a complete and holistic shift that embeds digital capabilities within business processes, strategies, and models to fundamentally alter how organizations operate and create value (Morakanyane et al., 2017). This transformation is defined by the integration of digital tools to boost operational efficiency, enhance customer experiences, and facilitate the development of new business models (Berman 2012).

Digital transformation extends beyond simple process automation; it involves a fundamental reshaping of business models, processes, and organizational structures to take full advantage of digital technologies. This transformation weaves digital strategies throughout every part of a business, allowing companies to streamline operations, reimagine customer value delivery, drive innovation, and stay competitive in a fast-changing market (Matt et al., 2015).

2.2 Digital Transformation in Engineering

Over the past three decades, the engineering industry has undergone a significant digital

shift. Engineering practices and project management have been transformed by the introduction of technologies like blockchain, the Internet of Things (IoT), Artificial Intelligence (AI), and Building Information Modeling (BIM) (Bilal et al., 2016). For example, BIM offers a digital representation of a facility's physical and functional traits, enhancing collaboration, visualization, and decision-making across the entire project lifecycle.

According to Li, Hou, and Wang (2017), the Internet of Things (IoT) facilitates real-time data gathering and processing, greatly enhancing project oversight and management by providing valuable insights into equipment efficiency, environmental factors, and worker safety. AI and machine learning algorithms play a crucial role in predicting project outcomes, optimizing resource allocation, and identifying potential hazards before they become serious problems. In addition, cloud computing enables more efficient data storage and exchange, leading to improved collaboration between project stakeholders (Chen et al., 2020).

In process engineering, digital transformation tools such as process simulation and the Digital Twin have revolutionized how projects are managed. The Digital Twin allows engineers to simulate, predict, and optimize plant performance throughout the project lifecycle, integrating physical and behavioral properties. This approach enhances real-time collaboration and reduces errors, ensuring all data is synchronized and accessible across engineering disciplines, ultimately improving project execution and outcomes (De Beer & Depew, 2021).

Digital transformation in engineering intertwines digital technologies with business models, driving value through smart factories, sustainability initiatives, and product lifecycle management. The integration of technologies like machine learning (ML) allows for advanced topic modeling and analysis of digital transformation trends, helping to identify key areas such as public infrastructure and business model-centric transformations in engineering and manufacturing systems. (Lee et al., 2021)

2.3 Engineering Project Management

Engineering project management applies knowledge, skills, tools, and techniques to project tasks to fulfill specific project requirements (PMI, 2017). Engineering projects have historically been managed using manual paperwork, sequential methods, and disconnected communication. These procedures often lead to errors, inefficiencies, and delays (Kerzner, 2017).

Engineering project management requires a strategic approach, particularly in environments that are constantly evolving. Traditional methods of project management, which rely heavily on deterministic practices, may not be sufficient to handle the complex and dynamic nature of modern engineering projects. Incorporating strategies that account for uncertainty and project complexity is crucial for successful outcomes (Klitgaard & Gottlieb, 2019).

Effective project management practices are essential in construction and engineering, offering a structured approach to planning, executing, and overseeing various project phases. These practices help mitigate risks, manage resources, and ensure project objectives are met within scope, budget, and timeline constraints, thus improving overall project outcomes (Shah et al., 2023).

These conventional methods have undergone tremendous modification due to the widespread use of digital tools and technologies. According to Gartner (2019), digital project management platforms facilitate seamless communication, centralized documentation, and real-time collaboration among project participants. Eadie et al. (2015) highlight that these platforms typically offer features like resource management, risk assessment, reporting, and project planning, all contributing to enhanced project effectiveness and efficiency.

2.4.Connecting Project Management and Digital Transformation

Several significant trends and advances are defining the intersection of engineering project

management and digital transformation. Whyte et al. (2016) note that integrating digital tools into project management has resulted in the development of novel approaches and methods. For example, the engineering industry has adopted agile project management due to its flexibility and iterative methodology in adapting to change (Conforto et al., 2014).

Studies indicate that enhancing the effectiveness and efficiency of project management significantly influences the behavioral intention to adopt and utilize digital technologies. This adoption is facilitated by the positive impact of digital transformation, which has been widely recognized in the literature. However, in-depth reviews of the wider digital transformation landscape within project management remain limited. A bibliometric analysis of 431 articles highlights the evolving methodologies and future directions for integrating digital tools into project management to drive greater efficiency and effectiveness. (Zornitsa Yordanova, 2024).

Furthermore, incorporating digital tools has facilitated the adoption of hybrid project management systems that combine the advantages of traditional and agile methodologies. According to Hoda, Noble, and Marshall (2013), using digital platforms for project planning and communication can lead to better stakeholder engagement as well as more effective project monitoring and reporting. Hwang and Ng (2013) state that digital transformation in project management includes leveraging big data and analytics to aid decision-making, streamline project timelines, and enhance resource management. Moreover, advanced analytics have positioned data-driven decision-making as a fundamental aspect of contemporary project management, enabling more accurate forecasting and risk management (Ahmad & Cuenca, 2018).

Several case studies illustrate the successful application of digital transformation within engineering project management. For example, BIM and other digital technologies were used to manage complex construction activities for the Crossrail project in the UK, increasing efficiency and reducing costs (Davies & Harty, 2013). The implementation of the Internet of Things and

artificial intelligence in smart building development has led to notable advancements in energy management and operational efficiency (Liu et al., 2020).

2.4 Theoretical framework

The study of digital transformation in engineering project management can be supported by different theoretical frameworks. The Technology-Organization-Environment (TOE) framework suggests that the adoption of new technologies is shaped by technological, organizational, and environmental factors (Tornatzky & Fleischer, 1990). This framework can help explain the different degrees of adoption of digital transformation in different engineering firms.

The Diffusion of Innovations (DOI) theory is also relevant, as it explores the processes, reasons, and pace at which new ideas and technologies are adopted within an organization (Rogers, 2003). This theory sheds light on the factors that either promote or impede the uptake of digital tools in project management.

The Resource-Based View (RBV) of the firm, which highlights the significance of organizational resources and competencies in achieving competitive advantage, is also highly relevant (Barney, 1991). This theory underscores the importance of developing digital skills and leveraging digital assets to enhance project management practices within the scope of digital transformation.

2.5 Gaps in the Existing Literature

Despite extensive research on digital transformation, numerous gaps require further investigation. A considerable gap exists in empirical research regarding the long-term impact of digital transformation on organizational performance and project results. Although many studies emphasize the short-term advantages of digital tools, there is little evidence of their long-term viability and value creation.

In addition, further research is needed to identify challenges and barriers to digital transformation in engineering project management. Resistance within the organization, insufficient digital skills, and inadequate infrastructure can obstruct the effective implementation of digital initiatives. Recognizing these limitations and developing strategies to address them is crucial for fully realizing the advantages of digital transformation.

Furthermore, existing research focuses primarily on the technological components of the digital transition, often ignoring the human and cultural dimensions. Future studies should address how digital transformation affects organizational culture, employee engagement, and leadership dynamics, as these aspects are critical to the successful adoption and integration of digital tools and technologies.

To summarize, while digital transformation offers a huge opportunity to improve engineering project management, it also creates obstacles that need to be addressed through extensive research and strategic planning. Addressing the gaps in existing literature allows researchers and practitioners to better understand the challenges of digital transformation and to craft more effective strategies for maximizing its advantages.

CHAPTER 3

RESEARCH PROBLEM

3.1 Problem Statement

The advent of digital transformation is causing rapid changes in the engineering sector by fundamentally altering traditional project management processes. Despite the potential benefits, effective adoption and integration of digital technologies remains a significant challenge for many engineering organizations. These difficulties include the high cost of implementing new technology, lack of digital skills, and aversion to change (Gartner, 2019). Furthermore, there is limited in-depth understanding of the specific impacts of digital transformation on project management practices and outcomes within the engineering sector. This research examines how engineering project management is affected by digital transformation to tackle these gaps, noting both the benefits and challenges for businesses in making this shift.

3.2 Problem Significance

Understanding how digital transformation affects engineering project management is essential for several reasons.

1. **Productivity and efficiency:** Digital technologies and tools can significantly increase the productivity and efficiency of projects. These solutions can result in more efficient project workflows and greater resource utilization by automating repetitive tasks, increasing data accuracy, and facilitating real-time collaboration (Li et al., 2018).
2. **Risk management:** By giving project managers better tools to track and anticipate potential problems, digital transformation can improve risk management. Proactive management is enabled, for example, by AI and machine learning algorithms that can

evaluate data from past projects to find trends and predict hazards (Panchal et al., 2019).

3. **Stakeholder Collaboration:** The success of engineering projects depends on the ability of stakeholders to work together effectively. According to Whyte et al. (2016), digital platforms enable better communication and information sharing, guaranteeing that all stakeholders are aware and agree throughout the project's lifetime.
4. **Competitiveness:** Engineering firms that effectively implement digital transformation methods can gain a significant competitive advantage in an increasingly competitive market. According to Golini et al. (2015), these companies are in a better position to complete projects on schedule, within budget, and with an appropriate level of quality.
5. **Sustainability:** By maximizing resource use, reducing waste, and increasing energy efficiency, digital technology can support more environmentally friendly engineering techniques (Liu et al., 2020).

However, the transition to digital project management is not without difficulties. Employees of engineering organizations who are used to established procedures often show a reluctance to change. New technologies also come with a steep learning curve, and it can be difficult for businesses to equip their employees with the necessary digital skills (Ozorhon & Oral, 2017). Significant barriers include the high cost of implementing new technology and concerns about data privacy and security (Mathews et al., 2020).

Considering these factors, an in-depth analysis of digital transformation's impact on engineering project management is essential. This research aims to provide insights that engineering firms can use to better navigate the path of digital transformation, maximize its benefits, and minimize its disadvantages.

CHAPTER 4

RESEARCH HYPOTHESES

4.1 Hypotheses Development

Based on the specified research problem and literature review, this chapter describes the hypotheses that form the basis of the research. These theories aim to provide a comprehensive analysis of how digital transformation has influenced the management of engineering projects. The purpose of the hypotheses is to evaluate individual aspects of digital transformation, such as the use of digital tools, adjustments to project workflows, and impacts on project outcomes.

1. Digital Transformation Increases the Effectiveness and Efficiency of Engineering Project Planning and Execution

According to research, digital tools such as BIM, AI, and IoT increase project productivity by automating repetitive processes, improving data accuracy, and enabling real-time collaboration (Bilal et al., 2016; Li et al., 2018). This theory is supported by this evidence. To test this theory, the relationship between the use of digital technologies and important efficiency measures such as project completion time and resource utilization will be investigated.

The study emphasizes that digital transformation greatly improves project management effectiveness and efficiency by embedding digital technologies, including AI, IoT, and big data analytics, into project workflows. DT in project management leads to improved resource management, optimized project schedules, and more accurate forecasting through data-driven decision-making (Alojail & Bhatia, 2023). By aligning digital transformation strategies with key efficiency measures like project completion time and resource utilization, companies can increase operational efficiency and effectiveness, driving better project outcomes.

2. Using Digital Tools and Technologies Improves Collaboration and Communication

Between Project Stakeholders

Collaboration and effective communication are essential to the realization of engineering projects. Digital platforms facilitate better coordination among stakeholders, centralized communication, and real-time information exchange (Whyte et al., 2016). To verify this hypothesis, the impact of digital platforms on stakeholder participation and the quality of project communication will be evaluated.

With the swift advancements in information and communication technology (ICT), new opportunities emerge for improving communication among participants from various organizations (i.e., internal stakeholders) involved in construction projects. Additionally, garnering the support of external stakeholders requires a well-planned approach, often facilitated by the use of ICT. Building Information Modeling (BIM) promotes collaboration among various stakeholders, enabling them to fulfill their roles by entering, accessing, updating, and sharing project information via the BIM platform (Prebanić & Vukomanović, 2021).

3. Despite its Benefits, Digital Transformation Comes with Challenges, such as Reluctance to Change and Significant Implementation Cost

Although digital transformation has many advantages, there are also many difficulties (Ozorhon & Oral, 2017). This hypothesis aims to investigate the obstacles to digital transformation and their impact on the adoption and effectiveness of digital technologies in project management.

The basic premise of this hypothesis is that digital technologies, especially AI and machine learning, provide better risk prediction and management skills (Panchal et al., 2019). This hypothesis will be tested by analyzing the effects of using digital tools on project risk

identification, assessment, and mitigation.

4. Engineering Firms that Implement Digital Transformation Techniques Achieved Improved Project Results in Contrast to Those that did not.

The basic premise of this hypothesis is that digital transformation improves project outcomes, including higher-quality outputs, lower costs, and happier clients (Golini et al., 2015). To assess this, the study will determine how well businesses are performing with different levels of digital transformation adoption.

This research seeks to provide a comprehensive insight into the impact of digital transformation on engineering project management by evaluating these theories. The findings will contribute to the existing knowledge base and inform future research and practice, providing insightful information to researchers and practitioners.

CHAPTER 5

RESEARCH OBJECTIVES

1.1 General Objectives

The primary goal of this study is to determine the impact of digital transformation on engineering project management. It aims to conduct an in-depth analysis of how digital tools and technologies are impacting project management practices, improving project outcomes, and dealing with the challenges engineering firms face as a result of this shift.

1.2 Specific Objectives

To fulfill the overarching objective, this research will concentrate on the following specific goals:

1. To Evaluate How Digital Tools and Technologies Impact Project Management Effectiveness.

The aim is to quantify how the use of digital tools such as IoT, AI, and BIM improves project efficiency. To determine the effectiveness of these tools, the study will evaluate some efficiency measures such as cost savings, resource utilization, and project completion time (Bilal et al., 2016; Li et al., 2018).

Digital transformation significantly enhances project management effectiveness by streamlining processes, improving resource utilization, and reducing completion time. Tools such as IoT, AI, and BIM offer real-time data insights, empowering project managers to make well-informed decisions that enhance resource allocation efficiency and reduce overall project costs. Furthermore, these tools facilitate better collaboration among stakeholders, which in turn increases project efficiency and leads to better outcomes (Ogunbukola, 2024).

2. To Investigate How Risk Management Practices in Engineering Projects are Affected by the Digital Transition.

The primary aim of this objective is to explore the impact of digital technologies on risk management. The study will focus on hazard prediction and control using AI and machine learning algorithms, as well as how these technologies improve overall risk management practices (Panchal et al., 2019).

Risk management is essential in engineering projects, particularly within the construction industry, where ensuring the safety of buildings, contractors, and workers is a top priority. Digital technologies like AI and machine learning, enable better prediction and control of potential hazards through real-time monitoring systems and data analysis. By integrating innovative building technologies with risk management practices, construction projects can proactively identify risks, leading to improved safety outcomes and a reduction in unpredictable hazards. The adoption of these technologies enhances the overall effectiveness of risk management by providing structured, organized processes for hazard identification and control, ultimately increasing the safety and quality of engineering projects (Zhao et al., 2024).

3. To Explore How Digital Platforms Can Improve Stakeholder Communication and Collaboration in Engineering Project Management.

Project success depends on effective stakeholder participation and communication. This objective will explore how digital platforms can improve stakeholder coordination, communication, and information sharing, which can lead to better project outcomes (Whyte et al., 2016).

4. To Compare Project Outcomes Between Engineering Companies that Use Digital

Transformation Techniques and Those that do not.

The aim is to evaluate how the digital transformation has affected the project results overall. This study will compare key performance indicators (KPIs), including client satisfaction, cost-effectiveness, and quality of outputs between companies with different degrees of digital transformation implementation (Golini et al., 2015).

5. To List and Explore the Difficulties Engineering Companies Face in Implementing Digital Transformation.

This objective aims to understand barriers to digital transformation such as excessive implementation costs, lack of digital skills, and resistance to change. In addition, to help engineering businesses move more smoothly, the research will look for possible ways to mitigate these difficulties (Ozorhon & Oral, 2017).

1.3 Significance of the Objectives

The specific objectives of this study are important for several reasons:

1. **Increase Efficiency:** Engineering businesses can make informed decisions about technology investments and process improvements by understanding how digital tools support project efficiency.
2. **Improve Risk Management:** By examining how digital transformation affects risk management, businesses can take proactive measures to reduce risk and increase project reliability.
3. **Fostering Collaboration:** Exploring how digital platforms could facilitate stakeholder collaboration can provide valuable insights into optimal methods of coordination and communication, ultimately leading to improved project outcomes.
4. **Benchmarking Performance:** To provide useful benchmarks and illustrate the benefits of

adopting digital methods, project results of companies with different degrees of digital transformation adoption should be compared.

5. **Addressing the Challenges:** By recognizing these barriers, businesses can create targeted plans to overcome them, facilitating a smoother transition and optimizing the benefits of digital technologies.

CHAPTER 6

RESEARCH IMPORTANCE

6.1 Theoretical Importance

This study adds to the body of knowledge already available on engineering project management and digital transformation, making it theoretically significant. By offering empirical data on the effects of digital tools and technologies on project effectiveness, risk management, stakeholder participation, and overall project outcomes, the study fills several gaps in the literature. The research contributes to our understanding of how traditional project management approaches in the engineering sector are being reshaped by digital transformation by examining these factors.

1. **Advances in Digital Transformation Theory:** This research expands upon existing concepts like the Diffusion of Innovations (DOI) and the Technology-Organization-Environment (TOE) framework. It offers fresh perspectives on the factors that impact the adoption and integration of digital technology in the industry by applying these theories to the engineering project management environment.
2. **Contribution to Project Management Knowledge:** Through the examination of how digital transformation influences key project management processes and outcomes, the study expands project management knowledge. This includes exploring new approaches such as agile project management and finding the best means to use digital tools to improve project performance (Conforto et al., 2014).
3. **Future Research:** The findings of this study lay the groundwork for further research on the digital revolution in engineering and other industries. The paper outlines the benefits

and pitfalls of digital transformation and highlights areas where more research is needed to develop practical plans for the adoption and fusion of new technologies.

6.2 Practical Importance

The finding has practical implications as it could help engineering firms in their digital transformation efforts. The report provides insights and insights to help businesses navigate the challenges of implementing and integrating digital technology into their project management practices.

1. **Improving Project Efficiency:** The research provides engineering businesses with evidence-based advice on technology investments by identifying digital tools and technologies that improve project efficiency. These insights can help firms reduce project completion times, maximize resource utilization, and improve project workflows (Bilal et al., 2016).
2. **Improving Risk Management:** Businesses can implement more proactive and successful risk management strategies using study findings on how digital transformation is impacting risk management practices. Enterprises can increase project reliability and reduce the likelihood of project failure by using artificial intelligence and machine learning to predict and mitigate risk (Panchal et al., 2019).
3. **Fostering Stakeholder Collaboration:** The study highlights how digital platforms can improve stakeholder communication and collaboration. These findings can be used by engineering firms to implement digital solutions that increase stakeholder coordination and information exchange, improving project outcomes (Whyte et al., 2016).

4. **Benchmarking and Best Practices:** For engineering organizations at various stages of digital transformation implementation, the study offers benchmarks and best practices. The research provides lessons and success stories that could help other organizations in their digital transformation efforts by comparing project outcomes between businesses with different levels of digital maturity (Golini et al., 2015).
5. **Coping with Implementation Challenges:** The study outlines the main barriers engineering businesses need to overcome to successfully implement digital transformation, including high implementation costs, lack of digital skills, and reluctance to change. By understanding these barriers, companies can formulate targeted approaches to overcome them and guarantee a smoother transition to digital project management (Ozorhon & Oral, 2017).

6.3 Societal Importance

In addition to theoretical and practical importance, this research also has societal significance. Successful adoption of digital transformation in engineering project management can lead to wider societal benefits, including improved infrastructure, increased safety, and more sustainable construction practices.

1. **Improved Infrastructure:** By improving efficiency and project outcomes, digital transformation can contribute to the development of better quality and more resilient infrastructure. This in turn can improve public services and the overall quality of life in communities (Liu et al., 2020).
2. **Increased Safety:** Digital risk management and real-time monitoring systems can

significantly increase safety on construction sites. This could lead to fewer accidents and injuries, protecting the safety of both the public and employees (Li et al., 2018).

3. **Sustainability:** By maximizing the use of resources, reducing waste, and increasing energy efficiency, digital technologies can support greener engineering techniques. This is consistent with global initiatives to mitigate climate change and promote environmental sustainability (Mathews et al., 2020).

In conclusion, this research has a wide range of implications, including theoretical, practical, and societal. Through a thorough examination of how digital transformation affects engineering project management, the study makes a significant contribution to knowledge that can inform future research in academia and industry.

CHAPTER 7

RESEARCH METHODOLOGY

7.1 Research Design

This study employs a mixed methods approach, integrating both quantitative and qualitative methodologies to thoroughly examine the impact of digital transformation on engineering project management. By combining quantitative data with complex findings, the mixed methods technique provides a comprehensive picture of the investigated phenomenon.

1. **Quantitative Component:** The quantitative aspect of the study centers on gathering and analyzing numerical data to assess hypotheses and measure the impacts of digital tools and technologies on project management effectiveness, risk management, stakeholder collaboration, and project outcomes (Creswell, 2014).
2. **Qualitative Component:** The qualitative component involves gathering comprehensive information through interviews and case studies to understand the difficulties and barriers engineering organizations face in adopting digital transformation, as well as to gain valuable insights into optimal strategies (Merriam & Tisdell, 2015).

7.2 Data Collection Methods

We will use the following methods to collect data for this study:

1. **Surveys:** Surveys will be designed to collect structured, quantifiable data from participants to evaluate the penetration of digital transformation tools, their perceived impacts, and their challenges in project management. The surveys will be developed using validated scales from prior studies in project management and digital transformation. Respondents will be asked to evaluate how the integration of digital tools such as BIM, AI, and IoT has

influenced project timelines, cost control, and resource management.

2. **Case Studies:** Detailed case studies will serve as a real-world exploration of how digital tools are applied in various engineering contexts. These case studies will not only focus on the outcomes of digital transformation but also the processes and organizational strategies that led to successful or unsuccessful implementations.
3. **Document Analysis:** Document analysis will involve reviewing project documentation, policies, and reports from engineering firms to understand their approach to digital transformation. These documents will provide additional context to supplement survey and interview data, allowing the researcher to assess consistency between reported practices and documented strategies.

7.3 Samples and Sampling Methods

The research sample will consist of engineering firms of various sizes and from various industries such as construction, manufacturing, and infrastructure. We will use a stratified sampling technique to ensure representation across all types of organizations and levels of digital transformation adoption.

1. **Sample Size:** The sample size will include approximately 200 individuals who will answer the survey and 20 individuals who will participate in the interview. In addition, we will create 5-10 comprehensive case studies.
2. **Sampling criteria:** We will consider the following factors when selecting samples:
 - Enterprises have integrated digital tools and technologies into their project management approaches.
 - Businesses that have not yet fully embraced digital transformation are considering implementing it.
 - Those directly involved in digital transformation activities within their organizations are known as key informants.

7.4 Data Analysis Methods

We will use the following methods to analyze the data for this study:

1. **Quantitative Data Analysis:** Survey data will be subjected to statistical analysis employing methods such as descriptive statistics, and regression analysis. These analyses will facilitate the identification of trends, and the influence of digital technologies on project management effectiveness, risk management, and outcomes.
2. **Qualitative Data Analysis:** We will use thematic analysis to analyze the interview and case study data. This task involves programming the data to recognize significant themes and patterns associated with the difficulties, approaches, and most effective methods of digital transformation in engineering project management.

3. **Mixed Method Integration:** We will combine results from both quantitative and qualitative analyses to offer a thorough understanding of the research problem, using an integrative mixed methods approach. We will use triangulation to verify the findings and ensure their reliability.

7.5 Assessment of Validity and Reliability

It is essential to guarantee the accuracy and reliability of research results.

1. Validity:

- **Construct Validity:** The incorporation of validated tools and metrics in the design of the survey ensures that the key concepts of digital transformation and project management are accurately measured.
- **Internal Validity:** The research design includes controls for potential confounding variables, such as firm size and industry type, to strengthen causal inferences.
- **External Validity:** By utilizing a representative sample of engineering companies, the results of this study will be generalizable to similar industry contexts.

2. Reliability:

- **Consistency:** The use of standardized data collection and analysis techniques will ensure that the study can be replicated, producing consistent results in future research.
- **Reproducibility:** All research processes will be thoroughly documented, enabling other researchers to replicate the study.

7.6 Ethical Considerations

Research places great emphasis on ethical considerations.

1. **Informed Consent:** Participants will receive detailed information about the aims, roles, and demands of the study to ensure their informed consent. All participants must give informed consent.
2. **Confidentiality:** We will maintain the privacy and security of the information participants provide to us and their responses. Data will be anonymized to protect the identity of participants and their respective organizations.
3. **Voluntary Participation:** Involvement in the study will be voluntary, and individuals may withdraw at any time without any repercussions.
4. **Data security:** Only the research team will have access to the secure data storage. We encrypt electronic information and securely store physical information on a device with limited access.

CHAPTER 8

RESEARCH LIMITATIONS

8.1 Methodological Limitations

Similar to any research study, this investigation has its limitations. Acknowledging these limitations is essential to understanding the scope and relevance of research findings.

1. **Sample Size and Generalizability:** While the sample size of approximately 200 survey respondents and 20 interview participants is sufficient for a mixed methods study, it may not be large enough to extrapolate the findings to all engineering businesses. The findings may speak more to the specific companies examined in the research than to the wider sector (Bryman, 2016).
2. **Sample Bias:** Despite the use of stratified sampling to ensure a representative sample, selection bias can still occur. Companies that have already implemented digital transformation may be more inclined to participate, shifting the results toward more positive perspectives of digital transformation (Creswell, 2014).
3. **Self-Reported Data:** Self-reported data obtained through surveys and interviews can lead to bias, as individuals may overestimate the benefits or downplay the difficulties of digital transformation. The accuracy of the findings may be affected by this (Podsakoff et al., 2003).
4. **Cross-Sectional Design:** The cross-sectional nature of a study suggests that data are collected at a specific point in time. This hinders the ability to evaluate changes over time and the lasting effects of digital transformation on engineering project management (Levin, 2006).

8.2 Practice Limitations

Obtaining specific project data and internal documents from engineering firms can be difficult due to confidentiality. The lack of availability of thorough data may hinder the scope of the study (Yin, 2018).

1. **Technological Differences:** This refers to significant differences among engineering organizations in their adoption and use of digital technology. The wide range of digital technologies and processes can be a challenge when trying to formulate universal conclusions that apply to all companies. This diversity is important to consider when analyzing the findings (Whyte et al., 2016).
2. **Implementation:** The implementation context of digital transformation, including factors such as organizational culture, management support, and the regulatory environment, can have a substantial impact on outcomes. Studies may not fully capture these contextual elements, limiting the ability to establish causal correlations.

8.3 Theoretical Limitations

1. **Scope of theories:** The study utilizes recognized theories, specifically the Technology-Organization-Environment (TOE) framework and the Diffusion of Innovations (DOI) theory, to gain insight into the digital transformation process in engineering project management. However, these theories may not comprehensively capture the complexity and many characteristics of digital change. Future research could be supported by the

inclusion of additional theoretical frameworks.

2. **Emerging Technologies:** The rapid pace of technological progress results in the constant emergence of new tools and activities. Study conclusions can quickly become outdated as new digital advances are developed and adopted. Ongoing research is essential to stay current with technological advances (Bilal et al., 2016).

8.4 Data Analysis Limitations

1. **Quantitative Analysis:** Although quantitative tools offer useful insights, they may not be able to capture the diverse experiences and opinions of participants. The statistical approaches used may have limitations in their ability to detect complex relations and interactions between variables (Field, 2013).
2. **Qualitative Analysis:** Thematic analysis of qualitative data depends on the researcher's interpretation, which may include subjectivity. Qualitative research, despite attempts to ensure reliability and validity, always has some level of interpretive bias (Braun & Clarke, 2006).

8.5 Ethical Limitations

1. **Participant Integrity:** Regardless of guarantees of confidentiality, individuals may still be hesitant to provide honest and comprehensive responses, particularly if they believe there are adverse consequences. The data obtained may be compromised by this (Orb et al., 2001).

2. **Informed Consent:** Securing informed consent can be a difficult task, especially when participants do not fully understand the implications of the research or when there are language barriers. It is essential to make efforts to reduce these problems, although they may not completely eradicate them (Creswell & Creswell, 2018).

To summarize, this research offers significant insight into how digital transformation affects engineering project management. However, it is crucial to consider these limitations when interpreting the findings. By acknowledging these limitations, researchers can direct their future investigations to fill these gaps and extend the findings of the current study.

CHAPTER 9

RESULTS

9.1 Overview

This chapter presents an overview of the findings derived from the collection of both quantitative and qualitative data through surveys, case studies, and document analysis. The findings are structured around the main research objectives and assumptions outlined in the previous sections and offer a full understanding of the effect of digital transitions on engineering project management.

9.2 Quantitative Findings

This section outlines the quantitative data obtained from the survey. The results are accompanied by charts and graphs that visually depict the key findings. The survey was designed to assess the adoption of digital tools in engineering project management and their impact on project outcomes, risk control, and stakeholder collaboration.

1. Survey Demographics:

A total of 200 respondents participated in the survey, coming from diverse roles such as engineers, project managers, and IT specialists across various sectors, including construction, manufacturing, and infrastructure.

- **Experience Breakdown:** Most respondents had between 3 to 10 years of experience, accounting for 60% of the total participants. This demographic split ensures the data covers insights from professionals with a broad range of experience levels.
- **Company Size Distribution:**
 - 30% of respondents work in large firms with over 500 employees.

- 40% of participants are employed in mid-sized companies (51-200 employees).

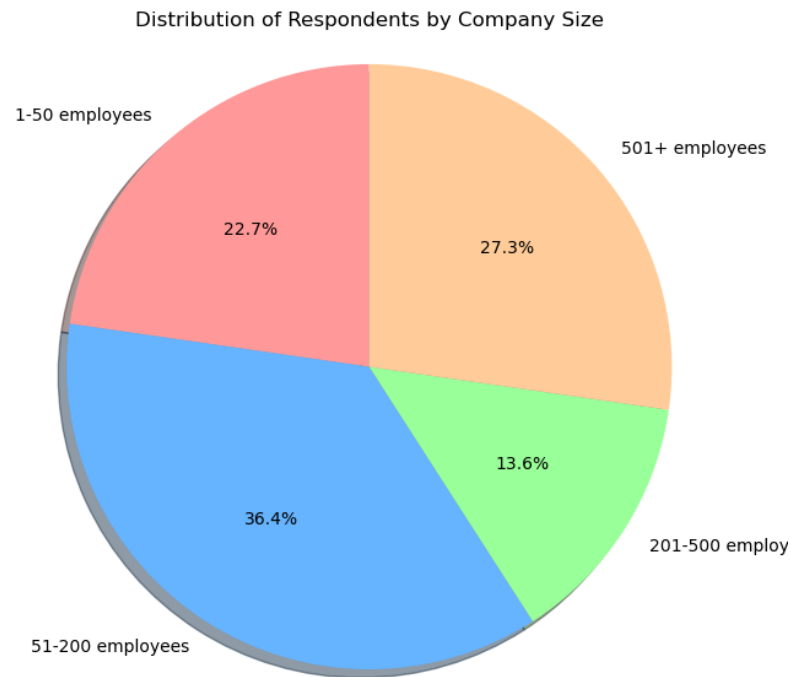


Figure 1: Company Size Distribution

2. Digital Tools Adoption:

The data suggests a high rate of digital tools adoption within the surveyed engineering firms. 85% of respondents indicated their companies had integrated at least one digital tool into their project management practices.

- **BIM Adoption:**

- **40%** of firms have fully adopted Building Information Modeling (BIM).
- **35%** have partially adopted BIM.
- **25%** are still in the planning stage or have not adopted BIM.

- **Cloud Computing and Project Management Software:**

- **50%** of respondents reported full adoption of cloud computing in their project management.
- **60%** confirmed that project management software had been fully integrated into their workflows.

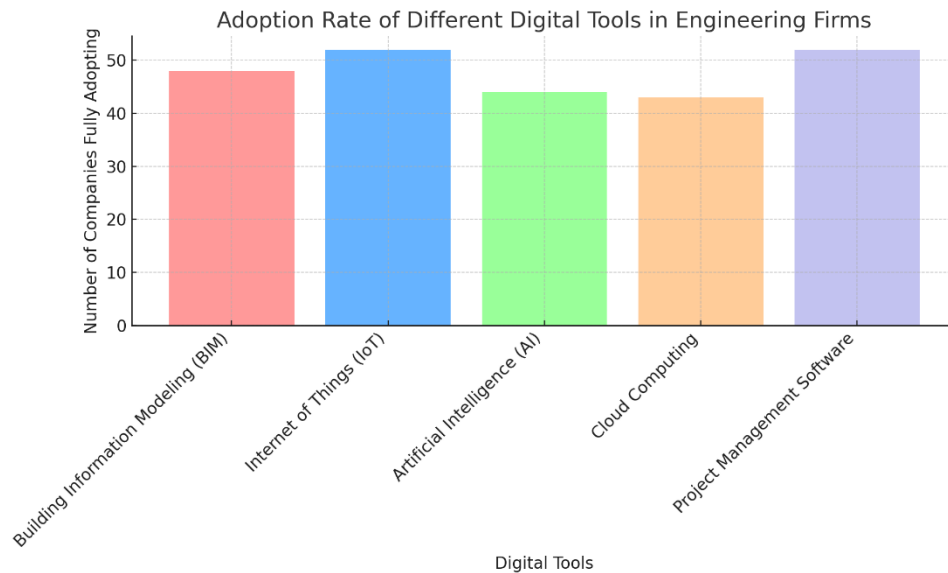


Figure 2: Digital Tools Adoption

3. Impact on Project Management:

The survey data shows a significant positive impact on project management effectiveness because of adopting digital tools:

- **Project Completion Rates:** Companies that adopted digital tools experienced a 25% increase in project completion rates.
- **Reduction in Delays:** Respondents indicated a 20-30% decrease in project delays following the implementation of digital technologies.

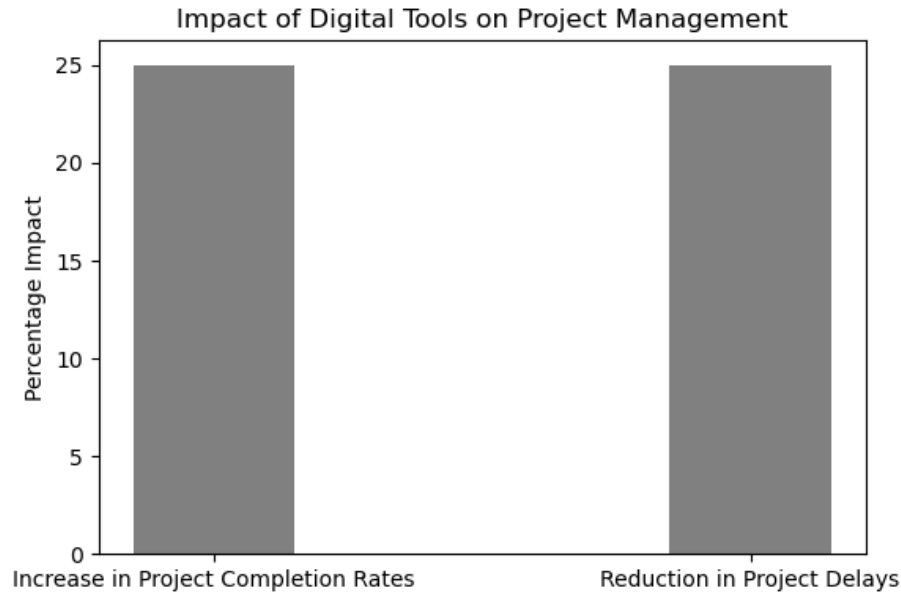


Figure 3: Impact of Digital Tools on Project Management

4. Risk Control:

The use of digital tools has significantly improved risk management practices in engineering project management. According to the survey data, firms that have adopted digital technologies experienced a 20% improvement in risk identification and mitigation. About 60% of respondents indicated that their capacity to manage project risks enhanced following the implementation of digital tools such as Building Information Modeling (BIM), Artificial Intelligence (AI), and the Internet of Things (IoT). These technologies have been especially effective in detecting potential risks early and providing solutions to mitigate them before they escalate.

The quantitative findings are supported by the insights gathered from case studies. For instance, in the Healthcare Expansion Project in Charlotte, North Carolina, BIM enabled the identification of 560 clash conflicts between mechanical, electrical, and plumbing (MEP) systems and structural elements, which were resolved before construction began. This early intervention prevented costly delays and rework, saving the project an estimated \$220,000. Similarly, in a smart manufacturing facility in Cork, Ireland, a data-driven analytics platform utilizing IoT and AI improved

the facility's ability to monitor operational risks in real-time, leading to a 30% reduction in operational risks. These findings demonstrate that digital tools not only enhance risk identification but also enable more efficient risk mitigation strategies.

5. Stakeholder Collaboration:

Digital transformation has also positively affected stakeholder collaboration and communication. Approximately 70% of respondents agreed that the use of digital tools has improved communication between teams and stakeholders, leading to better decision-making processes.

- **Collaboration and Communication:** The data also revealed that firms that adopted digital technologies saw a 20% increase in stakeholder satisfaction due to better collaboration practices.

9.3 Qualitative Findings

Interviews and case studies highlighted several barriers to digital transformation within engineering firms. Among the most common challenges were:

- **Reluctance to adapt:** Many employees and middle managers were hesitant to adopt new digital technologies, fearing disruptions to their established workflows.
- **Lack of digital expertise:** A recurring issue was the shortage of skilled personnel capable of using new digital tools effectively. Respondents noted that employees often lacked the necessary digital literacy and technical skills.
- **High costs:** The significant financial burden of implementing new technologies was cited as a major deterrent. Many organizations, especially smaller firms, struggled with the upfront investment in infrastructure and training.

Interviewees emphasized the need for ongoing training and consistent support to overcome these challenges. Several respondents suggested that digital transformation efforts often stall without proper leadership and a clear roadmap.

1. Exemplary Methods:

The case studies shed light on several key strategies that companies successfully employed to navigate the digital transformation process:

- **Strong leadership:** Leadership played a pivotal role in ensuring digital transformation efforts gained traction. Senior managers who championed the use of digital tools were instrumental in driving adoption and overcoming resistance.
- **Clear communication:** Firms that communicated the benefits of digital technologies such as cost savings, better project tracking, and efficiency improvements experienced more enthusiastic uptake from employees.
- **Cultural support for innovation:** Organizations that fostered a culture of improvement and innovation saw smoother transitions to digital tools. Interviewees noted that firms with strong innovation cultures also tended to have higher employee engagement in digital initiatives.

These strategies proved most effective when digital transformation efforts were integrated into broader business goals and not treated as standalone projects.

2. Impact on Project Outcomes:

The qualitative analysis supported the quantitative findings and confirmed that digital transformation had a significant positive impact on project outcomes:

- **Improved project quality:** Respondents highlighted that the use of digital tools resulted in fewer errors and better project execution, leading to improved deliverable

quality.

- **Cost reductions:** Several firms reported reductions in project costs due to better resource management and streamlined processes.
- **Enhanced client satisfaction:** The ability to monitor projects in real-time and quickly adjust plans resulted in higher client satisfaction. Firms that had fully adopted digital tools reported improved client relationships and increased repeat business.

9.4 Case Studies

- **Case Study 1: Healthcare Expansion Project, Charlotte, North Carolina**

In a \$44 million healthcare expansion project located in Charlotte, North Carolina, the construction manager, Rogers Builders, utilized Building Information Modeling (BIM) to enhance coordination and streamline the construction process. The project involved a 110,000 square-foot expansion using modular construction techniques, specifically prefabricated concrete panels for floor slabs. BIM played a key role in managing interdisciplinary collaboration, ensuring the seamless integration of mechanical, electrical, plumbing (MEP) systems, and structural components.

One of the most notable benefits was the identification and resolution of 560 clashes between MEP systems and structural components before fabrication, which helped to avoid significant delays and rework. The implementation of BIM also resulted in significant cost savings, with the project saving an estimated **\$220,000**. In addition, BIM was instrumental in automatically generating accurate quantity takeoffs for materials like structural steel, facilitating better cost management and work scope definition for subcontractors. This case illustrates the significant advantages of BIM in modular construction, particularly in managing complex projects with extensive system coordination (Lu & Korman, 2010).

- **Case Study 2: Implementation of Data-Driven Industrial Analytics for Smart Manufacturing**

In a sizable manufacturing facility located in Cork, Ireland, a data-driven industrial analytics platform was implemented to enhance operational efficiency and improve performance monitoring. The focus was on identifying and resolving operational issues in the facility's Air Handling Units (AHUs). Real-time data from sensors within the AHUs was collected and integrated into a cloud-based platform using Amazon Web Services (AWS). This system enabled continuous monitoring and analysis of large-scale operational data, facilitating quicker identification and resolution of inefficiencies, particularly related to energy consumption and equipment performance.

The implementation of this industrial analytics methodology yielded significant benefits. It resulted in improved operational efficiency by identifying performance issues that could be addressed promptly. The real-time data collection enabled factory managers to make informed decisions using current performance insights. Additionally, the platform's scalability demonstrated its capacity to integrate across multiple teams and systems, making it adaptable for future expansion. This case highlights the critical role of data analytics in driving operational improvements and efficiency in smart manufacturing environments (O'Donovan et al., 2020).

- **Case study 3: Integration of BIM, IoT, and Blockchain Technologies in Smart Building Design**

A case study was carried out to explore the integration of Building Information Modeling (BIM), the Internet of Things (IoT), and blockchain technologies in the design of a smart building. This study centered on a proposed smart museum design that leveraged these technologies to improve data management, operational efficiency, and security.

The BIM model served as the core framework, enabling virtual 3D modeling of the physical building, allowing real-time monitoring and management using IoT. Data collected from IoT devices within the building, such as sensors and smart devices were continuously processed and stored using blockchain technology to ensure data integrity, security, and immutability. This integration of blockchain allowed for secure, traceable data management, reducing the risk of tampering and ensuring transparency.

The implementation of this system design provided several benefits, including improved building management, enhanced security for physical and digital assets, and real-time decision-making capabilities. The smart museum design was scalable and could be implemented in various building categories, such as hospitals, offices, and industrial buildings. The framework facilitated better collaboration among stakeholders, ensuring efficient operations, data security, and sustainable building management (Lokshina et al., 2019).

9.5 Thematic Analysis

Thematic analysis of the qualitative data revealed several significant themes that shed light on the challenges and strategies related to digital transformation in engineering firms. The analysis identified three key themes: barriers to digital transformation, exemplary methods for successful adoption, and the impact of digital tools on project outcomes. These themes are discussed in detail below.

1. Barriers to Digital Transformation

One of the most recurring themes across interviews and case studies was the reluctance to adopt new technologies. Many employees and middle managers were hesitant to embrace digital tools, fearing that the transition would disrupt established workflows. This resistance was often linked to a

lack of digital expertise within firms. Respondents frequently noted a shortage of employees with sufficient technical skills or digital literacy to effectively use new tools, which further delayed adoption efforts. Moreover, the significant expenses related to the adoption of digital technologies were identified as a key challenge, especially for smaller companies. The significant financial burden of upfront investments in infrastructure and employee training was seen as a deterrent to digital transformation.

Sub-themes:

- **Reluctance to Adapt:** Employee resistance to digital transformation due to concerns about workflow disruption.
- **Lack of Digital Expertise:** Insufficient digital literacy and technical skills among staff.
- **High Implementation Costs:** Financial barriers to adopting new technologies, especially for smaller firms.

2. Exemplary Methods for Successful Adoption

Despite the barriers, the case studies and interviews revealed several effective strategies that firms employed to overcome resistance and facilitate digital transformation. Strong leadership emerged as a focal factor, with senior managers who championed the adoption of digital tools playing a crucial role in driving the change. Firms with leaders who consistently advocated for digital technologies and aligned them with business objectives were able to overcome resistance more effectively. Clear communication of the benefits, such as cost savings, improved project tracking, and increased efficiency also played a vital role in garnering employee support. Furthermore, organizations that fostered a culture of innovation and constant improvement experienced smoother transitions to digital tools. In these firms, employees were more engaged in digital initiatives, seeing them as part of a broader effort toward innovation.

Sub-themes:

- **Strong Leadership:** Leaders advocating for digital transformation and aligning it with business goals.
- **Clear Communication:** Transparent communication about the benefits of digital tools to encourage adoption.
- **Cultural Support for Innovation:** A company culture that fosters continuous improvement and innovation supports smoother transitions.

3. Impact of Digital Tools on Project Outcomes

The final theme that emerged from the analysis was the **positive impact of digital tools** on project outcomes. Both interviews and case studies confirmed that digital transformation had a substantial effect on improving **project quality**, reducing **costs**, and enhancing **client satisfaction**. Digital tools such as Building Information Modeling (BIM), cloud computing, and data-driven analytics were credited with reducing errors and improving project execution, leading to higher-quality deliverables. Additionally, several firms reported **cost reductions** due to better resource management and streamlined processes. Enhanced **client satisfaction** was also a recurring benefit, as digital tools allowed for real-time project monitoring and rapid adjustments, improving responsiveness to client needs and fostering stronger relationships.

Sub-themes:

- **Improved Project Quality:** Fewer errors and better project execution through the use of digital tools.
- **Cost Reductions:** Reduced project costs due to more efficient resource management.
- **Enhanced Client Satisfaction:** Real-time project tracking and improved client relationships through digital transformation.

9.6 Summary of Results

The results indicate that digital transformation in engineering project management has had a significant positive impact. Quantitative data indicate significant adoption rates of digital tools such as BIM and cloud computing, which have contributed to better project completion rates, enhanced risk management, and improved collaboration among stakeholders. Qualitative insights highlight challenges including resistance to adoption, insufficient digital skills, and high costs. Nevertheless, effective strategies for overcoming these obstacles included strong leadership, transparent communication, and the promotion of an innovative culture, leading to improved project quality, cost savings, and greater client satisfaction.

CHAPTER 10

DISCUSSIONS

10.1 Overview

This chapter provides an analysis of the data presented in the previous chapter and interprets the results of the current literature and theoretical framework. The debate will explore the implications of digital transformation for engineering project management, the importance of findings, and their relevance to research hypotheses and objectives.

10.2 Analysis of Quantitative Findings

1. Descriptive Statistics:

The survey data was examined through descriptive statistics to uncover the main trends in digital tool adoption for project management and its impact on managing project risks. The dataset included responses from 200 individuals across various industries. Each respondent provided insights on the adoption of five key digital tools: Building Information Modeling (BIM), Internet of Things (IoT), Artificial Intelligence (AI), Cloud Computing, and Project Management Software.

The results indicate a strong shift towards the adoption of digital tools across the respondents. Overall, 75% of respondents have adopted at least one of the digital tools in their project management practices.

- **Internet of Things (IoT)** emerged as the most widely adopted tool, with **79%** of respondents indicating its use.
- **Artificial Intelligence (AI)** was the second most adopted tool, with an adoption rate of **76.5%**.
- **Project Management Software** was adopted by **75%** of respondents, reflecting its

widespread use in coordinating and overseeing project activities.

- **Cloud Computing** showed an adoption rate of **72.5%**, indicating its growing importance in project data storage and accessibility.
- **Building Information Modeling (BIM)**, while commonly used in construction and infrastructure projects, was adopted by **72%** of respondents.

The data demonstrates a clear trend towards digitalization, with IoT, AI, and Cloud Computing being particularly influential in transforming project management processes. This high level of adoption highlights the increasing reliance on advanced digital tools to enhance efficiency, collaboration, and risk management in complex projects. Such widespread adoption supports the growing integration of technology in risk management strategies, reflecting the importance of digital transformation in modern project management.

2. Regression Analysis:

In this research, a logistic regression model was utilized to examine the relationship between the adoption of digital tools, specifically Building Information Modeling (BIM), Internet of Things (IoT), Artificial Intelligence (AI), Cloud Computing, and Project Management Software and their effects on improving project risk management. The binary classification of "Adopted" or "Not Adopted" was applied to each digital tool to simplify the analysis, while the target variable was whether or not project risks were effectively managed.

Model Overview

The logistic regression model was developed using 80% of the data, while the remaining 20% served as the test set. The model achieved an accuracy score of 80%, suggesting that the adoption of digital tools can reliably predict improvements in risk management for projects.

Interpretation of Coefficients

The regression coefficients represent the log odds of improved risk management given the adoption of a specific digital tool. A positive coefficient suggests that the tool increases the likelihood of effective risk management, while a negative coefficient suggests the opposite.

The coefficients for each digital tool are as follows:

1. **Building Information Modeling (BIM): -0.22**

BIM has a slightly negative association with the likelihood of improving project risk management, indicating that its adoption alone may not strongly contribute to better risk management in the projects under study.

2. **Internet of Things (IoT): 0.06**

IoT shows a small positive relationship with risk management improvement. While the effect is minimal, the adoption of IoT technologies might provide slight improvements in managing risks.

3. **Artificial Intelligence (AI): 0.48**

AI demonstrates a significant positive association with risk management. This suggests that the use of AI in project management may provide substantial benefits in terms of identifying, mitigating, and managing risks effectively.

4. **Cloud Computing: 0.08**

Cloud Computing also has a small positive effect on risk management. The flexibility and accessibility of cloud-based tools could offer marginal improvements in how project risks are managed.

5. **Project Management Software: -0.48**

Interestingly, Project Management Software exhibits a negative relationship with risk

management improvement. This could indicate that, despite its widespread use, traditional project management software may not directly contribute to risk mitigation, or that its effectiveness may be contingent on other factors not captured in this model.

Discussion

Among the tools analyzed, Artificial Intelligence (AI) has the most notable positive impact on improving project risk management, while Project Management Software and Building Information Modeling (BIM) show negative associations. These findings suggest that while digital transformation is important, not all tools provide equal benefits in the context of risk management. AI's higher positive impact could be attributed to its advanced capabilities in predictive analytics, pattern recognition, and decision-making, which are crucial for managing complex project risks.

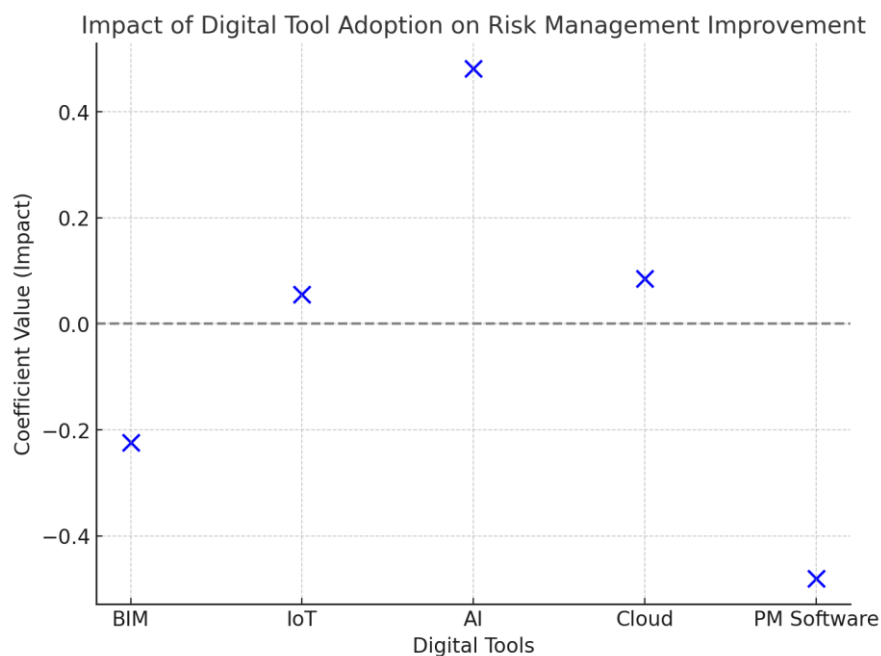


Figure 4: Impact of Digital Tool on Risk Management

10.3 Analysis of Qualitative Findings

The qualitative findings from interviews and case studies reveal critical insights into the

barriers to digital transformation and its overall impact on engineering project management. These findings underscore the multifaceted challenges firms face when adopting digital technologies and highlight essential strategies that can lead to improved project management outcomes.

Barriers to Digital Transformation in Engineering Project Management

1. **Reluctance to Adapt:** A notable barrier to digital transformation in engineering project management is the resistance to change among employees and middle managers. Many individuals expressed hesitance to adopt new digital technologies, fearing disruptions to established workflows and project processes. This reluctance indicates a need for comprehensive change management strategies that can foster a culture of adaptability and demonstrate how digital tools can enhance project efficiency and outcomes.
2. **Lack of Digital Expertise:** The qualitative findings indicate a recurring issue with the shortage of skilled personnel capable of effectively utilizing new digital tools within project management contexts. Respondents observed that employees frequently lacked the essential digital literacy and technical skills, which impedes the effective implementation of digital technologies. This gap in expertise can lead to suboptimal project management practices and decreased productivity. To address this issue, firms must prioritize ongoing training and professional development tailored specifically to the skills required for digital project management tools.
3. **High Costs:** The financial burden associated with implementing new digital technologies was cited as a major deterrent for many engineering firms. This barrier is particularly pronounced for smaller organizations, which often struggle with the upfront investment required for infrastructure and training. Without addressing this concern, firms may miss out on the significant benefits digital transformation can offer in project management efficiency.

Organizations can explore alternative funding strategies or phased implementation approaches to mitigate these costs while pursuing digital transformation initiatives.

Impact of Digital Transformation on Engineering Project Management Outcomes

The qualitative analysis supports the quantitative findings, confirming that digital transformation has a significant positive impact on engineering project management outcomes in several key areas:

- **Improved Project Quality:** Respondents highlighted that the use of digital tools within project management processes resulted in fewer errors and enhanced execution, leading to improved quality of deliverables. This improvement emphasizes the potential of digital technologies to streamline workflows and reduce mistakes, thereby enhancing overall project success.
- **Cost Reductions:** Many firms reported notable reductions in project costs due to better resource management and streamlined processes facilitated by digital tools. These cost savings can be attributed to increased efficiency in project planning, execution, and monitoring, allowing engineering firms to allocate resources more effectively and reduce waste.
- **Enhanced Client Satisfaction:** The ability to monitor projects in real time and make swift adjustments has led to higher levels of client satisfaction. Firms that fully adopted digital project management tools reported improved relationships with clients and increased repeat business. This responsiveness highlights the importance of adaptability and effective communication in meeting client needs, ultimately contributing to the long-term success of engineering projects.

10.4 Analysis of Case Studies

1. Healthcare firm Rogers Builders' introduction of BIM in the Charlotte expansion project has led to substantial improvements in project coordination and cost savings, emphasizing the transformative potential of digital tools. Empirical evidence from Lu & Korman (2010) shows that using BIM helped resolve 560 design conflicts and saved an estimated \$220,000, underscoring the positive impact of BIM on complex projects.
2. Manufacturing firm in Cork successfully implemented data-driven industrial analytics and IoT technologies, resulting in enhanced operational efficiency and real-time decision-making capabilities. The case highlights the practicality of integrating these technologies, leading to quicker identification of performance issues and improved resource allocation (O'Donovan et al., 2020).
3. A proposed smart museum's integration of BIM, IoT, and blockchain technologies improved data management, security, and operational efficiency, showcasing the benefits of these technologies for smart building design. The case study by Lokshina et al. (2019) illustrates how this integrated approach fosters collaboration and ensures sustainable building management across various industries.

10.5 Thematic Analysis

1. **Organizational Preparedness:** Organizational digital transformation centers significantly on strong leadership and a culture that embraces change. Visionary leadership is necessary to foster an innovation-driven environment that can effectively navigate the complexities of digital adoption. A clear digital strategy aligned with organizational culture is crucial to mitigate resistance to change and ensure successful implementation (Omol et al., 2023).
2. **Capacity Development:** It has become essential to equip employees with the necessary digital skills. The aforementioned discovery highlights the necessity of continuous investment in personnel development to sustain digital transformation efforts (Ozorhon & Oral, 2017).
3. **Strategic Positioning:** It is critical to the coherence and success of digital transformation activities, as it ensures that these initiatives align with the company's overall plan. This theme advocates incorporating digital transformation into the strategic planning process (Conforto et al., 2014).
4. **Technology Integration:** Seamlessly incorporating digital technologies into current processes is critical to optimizing the benefits of digital transformation. The theme underscores the importance of careful planning and implementation of digital integration initiatives (Li et al., 2018).
5. **Continuous Improvement:** The effectiveness of digital transformation initiatives is supported by an emphasis on innovation and continuous improvement. This finding is consistent with the notion of a learning organization that constantly adapts and evolves in response to emerging technologies and market conditions (Senge, 1990).

10.6 Impacts on Engineering Project Management

1. **Increased Project Efficiency:** The results of the study indicate that digital transformation has a substantial impact on improving project efficiency.
2. **Enhanced Risk Management:** Engineering businesses can use digital tools to optimize workflows, minimize delays, and increase overall project performance.
3. **Improved Stakeholder Collaboration:** Digital transformation facilitates better collaboration between project stakeholders. Improved communication and coordination lead to more effective decision-making and increased stakeholder satisfaction.
4. **Challenges and Strategies:** To achieve a successful digital transformation, engineering businesses must allocate resources to some specific areas like change management methods, continuous learning initiatives and obtain unwavering support from strong executives to overcome obstacles.

10.7 Limitations and Future Research

1. **Study Limitations:** Limitations include the relatively small sample size, potential selection bias, and the use of a cross-sectional design. Further research is needed to address these limitations and explore additional areas by using larger and more diverse samples, longitudinal designs, and more rigorous data collection methods.
2. **Future Research:** Future research should focus on examining the lasting effects of digital transformation on engineering project management, analyzing the impact of future technologies, studying the specific approaches companies use to overcome barriers to digital transformation, and conducting comparative research across different industries could provide insight into the extent to which findings can be universally applied.

CHAPTER 11

CONCLUSION

11.1 Overview of Key Discoveries

The study examined the impact of digital transformation on engineering project management and revealed several notable findings:

1. **High Rate of Adoption:** Most engineering organizations have widely adopted digital tools, indicating a general recognition of their benefits.
2. **Increased Project Efficiency:** Digital transformation is associated with substantial increases in project efficiency, such as increased completion rates and reduced delays.
3. **Advanced Risk Management:** Digital tools enhance risk management methods and enable organizations to identify, assess, and mitigate risks more effectively.
4. **Improved Stakeholder Collaboration:** The use of digital tools enables better communication and collaboration between project stakeholders, leading to more effective decision-making and increased stakeholder satisfaction.
5. **Barriers and Challenges:** Key barriers to digital transformation are reluctance to embrace change, lack of knowledge of digital competencies, and significant implementation costs. Overcoming these obstacles requires effective leadership, ongoing training, and a well-coordinated approach to digital projects.

11.3 Practical Impacts

The results of this study have various practical implications for engineering companies:

1. **Strategic Implementation:** Companies need to be intentional about designing and executing digital transformation programs to ensure they align with their overarching business goals. This means setting clear goals, identifying appropriate digital resources, and formulating a strategic implementation plan.
2. **Leadership Traditions:** Effective digital transformation requires both strong leadership and a supportive organizational culture. Leaders should actively promote and support digital initiatives, effectively communicate the benefits they bring, and cultivate an environment that supports innovation and continuous improvement.
3. **Capacity Development:** Ongoing training and development programs are essential to equip employees with the necessary digital skills. Companies should allocate resources to training programs to ensure that their employees have the necessary skills to use digital tools effectively.
4. **Change Management:** Implementing effective change management strategies is essential to addressing and overcoming resistance to change. This includes involving employees in the transformation process, helping, and resolving any issues that may arise.
5. **Technology Integration:** Companies should prioritize the seamless integration of digital tools into current practices. It requires careful strategy, experimentation, and improvement to optimize the benefits of digital transformation.

11.4 Theoretical Impacts

This work improves the theoretical understanding of digital transformation in engineering project management:

1. **Validation of Theoretical Frameworks:** The results confirm that the Technology-Organization-Environment (TOE) framework and the Diffusion of Innovations (DOI) theory are suitable for understanding the digital transformation process in engineering project management.
2. **Identifying Critical Determinants:** The study identifies critical determinants that influence the effectiveness of digital transformation, including organizational readiness, learning and growth, strategic alignment, and technology assimilation. These characteristics can contribute to the development of future theoretical models and frameworks.
3. **Integration of New Technologies:** The study highlights the need for ongoing research into evolving technologies and their impact on project management. Future theoretical research should integrate the dynamic characteristics of digital technologies and their implications for practical use.

CHAPTER 12

RECOMMENDATIONS

12.1 Suggestions

Based on the findings of this study, the following recommendations are proposed for engineering companies:

1. **Create a Coherent Digital Strategy:** Companies should create a coherent digital strategy that clearly defines their goals, identifies the necessary digital resources, and offers a step-by-step implementation plan. This plan must be in sync with the overarching business objectives and include input from key stakeholders.
2. **Allocate Resources to Training and Development:** Regularly dedicating resources to training and development initiatives is essential for providing employees with the digital skills they need. Organizations should provide ongoing training opportunities, workshops, and resources to facilitate employee education.
3. **Cultivate a Nurturing Culture:** Establishing a supportive organizational culture is vital for successful digital transformation. Leaders should promote an innovative culture and encourage employee engagement and recognize employee contributions to digital initiatives.
4. **Implementing Effective Change:** Effective change management is critical to addressing resistance to change. This involves actively engaging employees, providing support, and addressing any challenges that may emerge during the transformation process.
5. **Prioritize Continuous Improvement:** Digital transformation is a continual process that necessitates ongoing enhancement and adaptation. It is imperative that companies

consistently evaluate their digital efforts, gather feedback, and make any necessary adjustments to ensure continued results.

12.2 Areas for Future Research

Potential future research could extend this topic by examining many areas:

1. **Longitudinal Studies:** This will offer valuable insights into the lasting effects of digital transformation on engineering project management and the gradual evolution of digital practices over a longer period.
2. **Compare and Contrast:** Comparative studies conducted across different industries and geographies can offer a more comprehensive understanding of the elements that influence digital transformation and the extent to which the findings can be applied to different situations.
3. **Leveraging on New Technologies:** Conducting research into new technologies such as artificial intelligence, blockchain, and augmented reality can offer valuable insights into their potential impact on engineering project management and help shape future digital strategies.
4. **Organizational Considerations:** Further investigation of organizational aspects that influence digital transformation, such as leadership styles, organizational culture, and employee engagement, could offer a deeper understanding of the catalysts for effective digital projects.

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