



**An-Najah National University**  
**Faculty of Graduate Studies**

**DIGITAL TRANSFORMATION IN  
CONSTRUCTION MANAGEMENT:  
ASSESSING THE READINESS OF  
PALESTINIAN COMPANIES**

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**This Thesis is Submitted in Partial Fulfillment of the Requirements for the Degree  
of Master of Engineering Management, Faculty of Graduate Studies, An-Najah  
National University, Nablus, Palestine.**

**2025**

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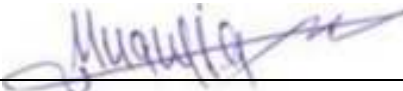
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Signature

## **Dedication**

To the one whose name I carry with pride and honor, my first teacher, my father Majed Qabaja

To the warm embrace perfumed with the fragrance of the homeland, my first support in life, my dear mother Hayat Qabaja

To my dear wife, Kinana Dababsa, who stood by me and supported me with all love

To my loving brothers who supported and encouraged me constantly

Thank you for everything.

## **Acknowledgements**

First and foremost, I thank and praise Allah, the Almighty, who gave me strength, patience and knowledge, and who was my support and helper during this academic journey, guiding my steps and facilitating the ways for me to complete this work successfully.

There is no doubt that this achievement would not have been possible without the grace of Allah first, and then the efforts of everyone who stood by me and supported me during this journey. I extend my sincere gratitude and appreciation to my honorable supervisor, Dr. Moawia Ramadan, for his efforts and sound guidance, and for the support, care, patience and continuous motivation he provided to me, which had a great impact on the completion of this research.

I would also like to express my deep gratitude to the faculty members of the Engineering Management Program at An-Najah National University, whose guidance and lessons were a fundamental pillar of this research. I thank the members of the discussion committee for their valuable time and efforts in reviewing and evaluating this work.

Finally, I would like to thank all the participants in this study, who kindly shared their experiences and knowledge, and whose contributions played a pivotal role in enriching and completing this research.

To all of you, my deepest thanks and gratitude.

## Declaration

I, the undersigned, declare that I submitted the thesis entitled:

# DIGITAL TRANSFORMATION IN CONSTRUCTION MANAGEMENT: ASSESSING THE READINESS OF PALESTINIAN COMPANIES

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: عزیز ماجد عزیز قباہ

Signature: عزیز قباہ

Date: 17/6/2025

# List of Contents

Dedication.....	iii
Acknowledgements.....	iv
Declaration.....	v
List of Contents.....	vi
List of Tables.....	viii
List of Figures.....	viii
List of Appendices.....	ix
Abstract.....	xi
Chapter One: Introduction.....	1
1.1 General Background.....	1
1.2 Problem Statement.....	4
1.3 Significance of the Study.....	5
1.4 Objectives.....	6
1.5 Research questions.....	7
1.6 Study Hypotheses.....	7
1.7 Thesis Structure.....	9
1.8 Literature Review.....	10
1.8.1 Digital Transformation and Artificial Intelligence.....	10
1.8.2 Digital Transformation in Construction Project.....	10
1.8.3 Digital Maturity.....	11
1.8.4 Applications of AI in Construction Project.....	12
1.8.4.1 Predictive Analytics.....	12
1.8.4.2 Risk Mitigation.....	15
1.8.4.3 Cost Control during the Project.....	17
1.8.4.4 Construction Site Assessment.....	18
Chapter Two: Research Methodology.....	21
2.1 Overview.....	21
2.2 Target population and sampling procedure.....	22
2.3 Questionnaire design.....	24

2.4 Qualitative Interviews.....	25
Chapter Three: Data analysis and results.....	26
3.1 Interviews analysis.....	26
3.2 Questionnaires analysis.....	29
3.2.1 Study population.....	29
3.2.2 Assessment of constructs implementation.....	31
3.2.3 Assessment of the measurement model.....	33
3.2.4 Assessment of the structural model.....	39
3.2.4.1 The determination coefficient ( $R^2$ ).....	39
3.2.4.2 The determination coefficient ( $R^2$ ).....	39
3.2.4.3 Predictive Relevance of the Model.....	40
3.3 Testing of Hypotheses.....	41
Chapter Four: Discussion and conclusions.....	43
4.1 Chapter overview.....	43
4.2 Discussion.....	43
4.3 Conclusions.....	48
Chapter Five: Strategy of Digitalization in Construction Sector Framework.....	49
5. 1 Chapter overview.....	49
5.2 Model development.....	49
5.2.1 Stakeholders and their role in digital transformation.....	50
5.2.2 Components of the proposed model.....	52
5.2.3 Model Success Factors.....	53
Chapter Six: Managerial Implications and Future Studies.....	55
6.1 Theoretical implications.....	55
6.2 Practical implications.....	55
6.3 Limitations and future research work.....	56
List of Abbreviations.....	58
References.....	60
Appendices.....	68
الملخص.....	ب

## List of Tables

Table 1: Active Registered Construction Companies .....	23
Table 2: Characteristics of the companies and role of the interviewees .....	25
Table 3: Demographic characteristics of the study sample .....	30
Table 4: Converting verbal answers according to the five-point Likert scale into numerical answers .....	32
Table 5: Evaluating the means of response degrees .....	32
Table 6: Levels of ADT, DM, and MP .....	33
Table 7: Results of reliability and validity analysis .....	35
Table 8: Discriminant validity check (square root of AVE is shown on the diagonal in bold) based on Fornell-Larcker criterion method .....	37
Table 9: Discriminant validity check using HTMT .....	37
Table 10: Assessment of formative constructs. ....	38

## List of Figures

Figure 1: The research model and proposed hypotheses .....	8
Figure 2: Big data innovation diffusion & the role of conflict in adoption .....	13
Figure 3: Neural network structure .....	14
Figure 4: EMLA Prediction Architecture. ....	16
Figure 5: Random Forest and Genetic Algorithm (RF-GA) structure .....	19
Figure 6: Research methodology .....	22
Figure 7: The results of PLS -algorithm for research model .....	35
Figure 8: PLS Bootstrapping (T-values) for the research model .....	42
Figure 9: Model for Digitalization in the Construction Sector .....	50
Figure 10: Proposed model for developing digital transformation .....	54

## List of Appendices

Appendix A: Questionnaire .....	68
Appendix B: Questionnaire.....	74
Appendix C: Multivariate Analysis (MANOVA).....	80
Appendix D: Model Fit.....	83
Appendix E: Results of R <sup>2</sup> , f <sup>2</sup> and Q <sup>2</sup> value.....	84
Appendix F: Hypothesis testing results .....	85

# **DIGITAL TRANSFORMATION IN CONSTRUCTION MANAGEMENT: ASSESSING THE READINESS OF PALESTINIAN COMPANIES**

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## **Abstract**

This study investigates the readiness of Palestinian construction companies to adopt digital transformation (DT) using artificial intelligence (AI) tools, while identifying associated challenges and proposing strategic solutions. In light of low productivity and marginal profit margins in the construction sector, DT is seen as a driver for improving project performance and innovation. The study evaluates how strategy, technological infrastructure, and human resources affect DT adoption and examines digital maturity as a mediating factor. A mixed-method approach was adopted. Qualitative data were collected through 13 semi-structured interviews, while quantitative data were obtained via a structured questionnaire distributed to 333 companies, with 143 valid responses (response rate: 42.9%). The Partial Least Squares Structural Equation Modeling (PLS-SEM) technique was used for data analysis. The findings reveal that the level of digital transformation adoption (ADT) was high (mean = 3.73/5), digital maturity (DM) scored a mean of 3.64, while project performance (MP) showed a very high level (mean = 4.18). Among ADT dimensions, technology had the highest influence (mean = 3.96), followed by strategy and human resources (mean = 3.62 each). The structural model showed strong, significant relationships between DT adoption and project performance ( $R^2 = 0.712$ ), with digital maturity partially mediating this relationship (VAF = 52%). Key challenges identified include weak digital skills, limited infrastructure, and regulatory constraints. In response, the study proposes a strategic framework that includes: (1) investment in modern digital infrastructure, (2) development of digital competencies, and (3) regulatory reform. These strategies aim to enhance digital adoption and ensure sustainable performance gains in the Palestinian construction sector. This research provides empirical evidence of DT readiness and contributes actionable solutions and policy recommendations to accelerate digitalization in developing construction markets.

**Keywords:** Digital Transformation, Artificial Intelligence, Construction Management, Digital Maturity, Palestinian Construction Companies, Project Performance, Strategic Framework, Technological Infrastructure, Human Resources, BIM, IoT.

# Chapter One

## Introduction

This chapter provides a general overview of this research. It includes a general background, research problem, research questions, aims and objectives of the research, significance of research and finally thesis structure.

### 1.1 General Background

Currently, the world is facing continuous challenges that have affected the work of the construction sector. To solve these challenges, engineering has thought about technology as it constantly evolves. The modern link between engineering and technology aims to improve the standard of living. Relying on advanced technical programs and artificial intelligence has become an urgent necessity in various fields, especially in the construction sector, as these tools play a major role in improving project management (Patil, 2019).

Kim et al. (2023), pointed out that using digital technology in the construction sector enhances the ability to manage projects effectively, through precise control of costs and schedules, which leads to more accurate and efficient results (Kim et al., 2023). The process involves using digital technology to manage all stages of the project from design to implementation. Digital tools such as project management software provide the ability to accurately track project progress and monitor budgets in real time, which facilitating decision-making and course correction in case of any deviation (Kim et al., 2023). Digitalization facilitates communication between all stakeholders such as engineers, contractors, and supervisors. This helps in effective coordination and reduces delays resulting from misunderstandings. The construction projects sector is an industry with significant impact at the local and international levels, but the sector has faced challenges of poor productivity and small profit margins (Pistorius, 2017).

Authoritative national and international publications highlight the construction industry (CI), construction projects (CP), construction management (CM), and construction companies (CB) (Patil, 2019).

The move towards digital platforms enhances the competitive environment, as digital technologies change how these projects are managed, and bring new benefits that

contribute to increasing efficiency and innovation, as this affects the areas of enterprise management, knowledge utilization, construction site optimization, and collaboration between projects. With the advances in the use of artificial intelligence in construction projects, several scientific questions arise: How can engineers adopt AI technologies in the construction field? And evaluating the pros and cons of applying artificial intelligence in construction operations (Patil, 2019).

Digital transformation is seen as developing an IT strategy related to all operations in the company, so digital transformation and the use and development of artificial intelligence applications have become a necessity for most companies to keep pace with technological developments in the world, but in the field of architecture and construction, digital transformation is relatively recent. Most traditional companies in this sector have not fully adopted digital transformation strategies (Mithas et al., 2011). This sector has historically relied on traditional methods of design and construction, which made it less responsive to technological developments compared to other sectors (Dolla et al., 2023). However, digital transformation has great potential to change business models in this field. Digital transformation allows design teams to operate concurrently across platforms like Building Information Modeling (BIM), facilitating real-time collaboration among designers, engineers, and contractors. This actually helps achieve earlier and more accurate design alternations which enhanced project management and modify risks. Such improvements resemble in the use of drones and laser scanning as tools that can accurately provide accurate positioning data. Yet, the ongoing use of digital transformation without having a well-established model of digital transformation can mostly cause uncertainty in the entire process (Mohammadi et al., 2023).

So, companies are expected to adopt certain strategies of digitalization whereby they need to have clear cut key roles, consider the impacts of such transformation on both social and environmental levels and finally state their technological and business objectives (Machado et al., 2021). The thought of emerging digital tools like the Internet of Things (IoT) and Artificial Intelligence (AI) into the real world of work has led to extreme methods of transformation (Zhou et al., 2018). Digital transformation has significantly help companies to modify and evolve business environment towards facing today's markets complexity and uncertainty. Here, digital transformation importantly

redefines typical models of business and reintroduce the concept of value through process and efficiency improvement beside that of customers. In consequent, the organizations with efficient competitive capacity enhancing their sustainability against constant market challenge (Hess et al., 2016; Veldhoven & Vanthienen, 2022; Verhoef et al., 2021).

With the growing awareness among practitioners, researchers and policymakers of the importance of digital transformation, it has become clear that these initiatives are not limited to enhancing the internal performance of companies, but rather constitute strategic tools that can bring about fundamental changes in the entire industry (Sebastian et al., 2017), Good management, from the researcher's point of view (Machado et al., 2021), depends on integrating data flows with stakeholders in order to expand the knowledge base and enhance communication according to the goals of digital transformation, and gain a comprehensive understanding of the appropriateness of the technological infrastructure, as well as the maturity level of digital technologies and artificial intelligence applications. These technologies are integral to digital transformation, with current examples including Building Information Modeling (BIM) programs and the utilization of drones for workflow monitoring (Chwiłkowska-Kubala et al., 2023).

Technology is a key element in accelerating the digital transformation in construction projects, contributing to improved efficiency, reduced costs, enhanced safety standards, and increased productivity levels. Digitally transforming data – images and texts into a likely binary code helps businesses improve their operational processes with great advantages on the customers' part (Berlak et al., 2021; Verhoef et al., 2021). This has urges both firms and governments worldwide to digital tools in the construction sector as significantly maintain their ability of market competitiveness and sustainability on long terms (Armstrong et al., 2019). In reality, human resources play a significant role in making the process of digital transformation truly efficient and more sustainable. In that, they contribute to develop innovative skills and facilitate the practical part of the change towards digitalization. This requires reviewing of the companies' HR system towards achieving a well-technologically developed system (Smirnova et al., 2019).

## **1.2 Problem Statement**

The industrial sector, including construction, tends to apply digital transformation. Construction companies has even gone beyond through emerging digital tools and artificial intelligence apps. This has actually signified the significance of digitalization, which helps simplify construction project management (Naji et al., 2024). Nevertheless, the complexity of construction projects usually impedes the standardization of digital solutions. This reflects the lack of unified strategies, inconsistent standards and regulations and a shortage of experienced leaders in digital transformation management (Machado et al., 2021). Moreover, the current staff lacks the required digitalization-related skills. To fill the gap, construction companies either need to provide the employees with intensive digitalization training programs or employ well-qualified people in the field. Here, companies are recommended to provide their employees with the required digital knowledge and experience to fully manage the emergence of such digital transformation in practice (Chwiłkowska-Kubala et al., 2023). More importantly, digital transformation maturity represents a significant factor as a medium between digital transformation in practice and those expectations to finally achieve. In fact, the higher the level of digital maturity, the better the status that a company is eligible to gain in terms of effectively adopting and integrating new tools of digitalization.

Digital Transformation has fundamentally become part of modernizing the construction sector companies so as to achieve efficiency and sustainability. To effectively implement digital solutions, construction companies need to state well-definite strategies, have eligible leadership, reinvest in their staff training, and afford more for development.

Since the Palestinian process of digitalization witness slowness, it requires a hard work to evaluate the current situation. The present study aims to evaluate the construction company's readiness and tendency to emerge digital transformation and the potential influence on their performance in a consequence.

### 1.3 Significance of the Study

The present study gains its significance as it addresses the major challenges that Palestinian construction companies face upon adopting digital transformation tools and emerging them into practice. Through assessing such companies' readiness to emerge in digitalization, the study looks into the gaps and opportunities for enhancing efficiency, innovation, and sustainability. Here, the study intends to make a theoretical framework of modernizing traditional practices, improving project management, and boosting competitiveness. So, the study is expected to provide valuable vision in response to the technological improvements and foster long-term growth in construction companies, Specifically, the study seeks to:

1. Bridging a knowledge gap in the Palestinian context, as there are no systematic quantitative or qualitative studies evaluating digital transformation in local contracting companies despite the accelerating global trend in this direction, especially in light of the increasing complexity of projects and the lack of digital competencies.
2. Providing an integrated scientific model based on statistical analysis using the PLS-SEM approach, linking three components (strategy, technology, and human resources) and the level of digital maturity, leading to their impact on project performance. This model provides an analytical tool that can be used later by researchers or other institutions.
3. Providing accurate quantitative data to decision-makers in the government, the Ministry of Public Works, and the Contractors Union regarding:
  - The availability of digital infrastructure within companies.
  - The extent of the digital skills gap.
  - The degree of companies' responsiveness to technological changes.
4. Proposing an executable digital strategy, based on real field results, that represents a roadmap for developing national policies in the field of digital transformation in the construction sector, in terms of:
  - Developing digital infrastructure.
  - Allocating financial or training support for contractors.
  - Formulating incentive guidelines linked to tenders or professional classification.

5. Enhancing the competitiveness of the Palestinian construction sector in a challenging economic and political environment by demonstrating how digital transformation can improve project quality, reduce costs, and increase adherence to schedules.
6. Linking digital transformation to strategic planning for national projects, enabling official bodies to make decisions based on digital indicators and real readiness models, rather than general estimates.

In brief, the present study gains its significance from the potentials to positively change the current practices of management in the field of construction projects, these changes really address today's challenges, enhance outcomes and contribute the progress generally achieved in instruction projects in the age of AI.

#### **1.4 Objectives**

The “Digital Transformation and Artificial Intelligence in Construction Projects” study is designed to guide the research process and achieve specific outcomes. The objectives are outlined as follows:

1. Analyzing the readiness of Palestinian construction companies to adopt digital transformation across three main axes:
  - Available technological infrastructure.
  - Adopted management strategies.
  - Digital human resource competency.
2. Assessing the level of digital transformation maturity among Palestinian companies, as an intervening variable linking companies' readiness to actual transformation in performance.
3. Measuring the direct and indirect relationship between digital transformation adoption and construction project performance in terms of:
  - Schedule (time).
  - Cost.
  - Quality.
  - Scope of work.
4. Developing an applied research model using the structural equation modeling (PLS-SEM) method to measure the impact of digital transformation on performance based on the level of digital maturity.

5. Drafting an initial national strategy for digital transformation in the Palestinian construction sector, which can be used as a reference for decision-makers and stakeholders.

Identifying the organizational, human, and technical challenges facing the digital transformation process, and proposing practical recommendations to address them at the institutional and political levels.

### **1.5 Research questions**

This study seeks to address the following key questions:

- RQ1: what extent are Palestinian construction companies ready to adopt digital transformation in terms of strategy, technological infrastructure, and human resources?
- RQ2: What is the level of digital transformation maturity in Palestinian construction companies, and what are the factors influencing this maturity?
- RQ3: How does adopting digital transformation impact construction project performance in terms of time, cost, quality, and scope of work?
- RQ4: What are the challenges facing Palestinian construction companies in achieving digital transformation, and what are the possible solutions from an administrative and technical perspective?
- RQ5: How can decision-makers use the results of this study to develop effective policies that support digital transformation in the contracting sector?

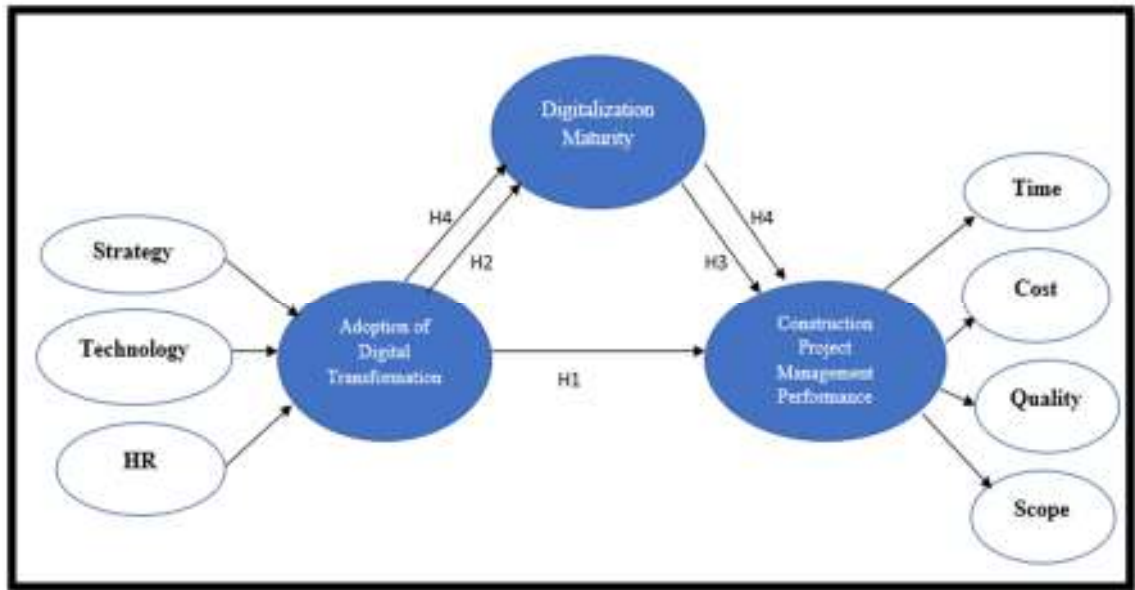
### **1.6 Study Hypotheses**

The study aims to study the readiness of Palestinian Construction Companies to adopt Digital Transformation through assessing the different aspects such as strategy, technology and human resources and their impact on adopting digital transformation by enabling digitalization maturity measuring criteria such as (technological infrastructure, workforce skills, organizational culture, financial capability, and regulatory environment), then studying the impact of digital transformation on measuring the performance of construction projects.

The figure below shows the conceptual model of this study which illustrates the impact of adopting digital transformation on the performance of construction project management by using digitalization maturity as a mediator in this relationship.

**Figure 1**

*The research model and proposed hypotheses*



Using the conceptual model provided, we can formulate hypotheses to explore the relationships between the adoption of digital transformation, the role of digitalization maturity as a mediating factor, and the performance of construction project management. The following hypotheses are proposed:

**H1:** (Strategy, Technology, and HR).

The Adoption of Digital Transformation has a Perceived Impact on construction project management performance:

- H1a: strategy positively influences the readiness of adoption of digital transformation initiatives.
- H1b: Advanced technology infrastructure positively influences the readiness of adoption of digital transformation initiatives.
- H1c: Skilled human resources (HR) positively influence the readiness adoption of digital transformation initiatives

**H2:** Adoption of Digital Transformation and Digitalization Maturity.

H2: There is a significant positive relationship between the adoption of digital transformation and reaching digitalization maturity.

**H3:** Enabling digitalization maturity.

H3: Enabling digitalization maturity significantly mediates the relationship between the adoption of digital transformation and construction project management performance.

**H4:** There is a significant positive relationship between digitalization maturity and construction project management performance.

H4: There is a significant positive relationship between enabling digitalization maturity and construction project management performance.

These hypotheses aim to test the direct and indirect effects of digital transformation adoption on project performance, considering the mediating role of digitalization maturity.

### **1.7 Thesis Structure**

The thesis is structured into Six chapters. The first chapter, Introduction, provides an overview of the research background, outlines the research problem, discusses relevant theories, and highlights the significance of the study. It also defines the research objectives, questions and Literature Review, examines existing research on artificial intelligence and its role in improving project productivity. It also explores topics such as automated planning, risk mitigation, cost control, and construction site evaluation, all within the context of advancing digital transformation.

The Second chapter, Methodology, details the research approach, including the data collection process, target population, sampling methods, and the development of data collection tools. It also explains the analytical methods used. In the Thread chapter, Data Analysis and Results, both quantitative and qualitative data are analyzed, and the findings from hypothesis testing are presented.

The Fourth chapter, Discussion and Conclusion, interprets the results from the thread chapter, draws conclusions about the validity of the hypotheses, and discusses their implications. The Fifth chapter, titled Digital Transformation Development Plan in Construction Companies, outlines a comprehensive strategy to support digital transformation within the sector. Finally, the Sixth chapter, Managerial Implications and Future Studies, highlights the practical and theoretical contributions of the research, addresses the challenges encountered, and offers recommendations for future studies.

## **1.8 Literature Review**

This chapter will review and analyze both empirical and theoretical data from existing literature to highlight the significance of digital transformation and the application of artificial intelligence technologies, as well as their influence on construction projects.

### **1.8.1 Digital Transformation and Artificial Intelligence**

Artificial intelligence is used as an effective tool in accelerating digital transformation processes, as it can analyze data and make smart decisions that enhance the performance of technological systems, making it one of the main drivers for developing modern technical solutions. It contributes to improving processes, analyzing data, and making decisions effectively. From an engineering perspective, artificial intelligence is used in analyzing and developing algorithms. Information is gaining much more value in a world with digital economy and effectively contributes well in companies' financial success in consequence. This actually enables companies to have well organized data, respond to variable changes and predict the future potentials. (Minbaleev, 2022). Additionally, Zaychenko et al. (2018) believe that digital transformation supported by AI tools can vitally help companies to reach their objectives and as their competitiveness. The integration of AI to digital transformation has positively affected various fields including; business management, construction companies, digital economy, human resources, healthcare, trade, community innovation, tourism and education (Zaychenko et al., 2018). consequently, decision makers can improve effective strategies, opting for the best ways of transforming into digitalization (Simoes et al., 2022).

### **1.8.2 Digital Transformation in Construction Project**

The construction sector often encounters project delays, low levels of productivity and decision-making reluctance due to inefficient and inadequate adoption of digital transformation with slow turning into AI. fortunately, this has witnessed changes in the recent years urging more eligibility for digital transformation on the echo of labor shortages and the recent effects of COVID-19 pandemic (Sacks et al., 2020). In fact, by emerging innovative tools in the mid-1980s., the construction and design companies' adoption of AI enhanced their development (Abioye et al., 2021). These improvements have locally and regionally and globally made management integration with the

construction projects such significant, in a way that improved productivity with elevation of the construction sector scales, i.e., the US construction sector showed a share of nearly \$900 billion during the first quarter of 2020. While maintaining high-quality standards, the construction sector has also emerged innovative technologies that reduce carbon emissions in cement production. Moreover, aiming to achieve more accurate and efficient building design, the design sector witnessed the emerge of simulation and 3D modeling supported by AI (Weber-Lewerenz, 2021).

### **1.8.3 Digital Maturity**

Digital maturity refers to the extent to which organizations develop and integrate digital technologies, strategies, culture, and processes to effectively compete in a digitally driven environment. This concept represents a gradual evolution from initial awareness of technology to a stage where digital innovation is a key driver of achieving a lasting and sustainable competitive advantage (Aras & Büyüközkan, 2023). The concept of digital maturity has gained increasing attention as organizations around the world increasingly recognize the importance of digital transformation as a critical factor for survival and growth.

In the same context, several models have been developed to assess the level of digital maturity of organizations and guide them through their digital transformation journey, which often encompasses multiple dimensions such as technology, strategy, culture, governance, and organizational capabilities. For example, Aras and Boykozkan (2023) presented a comprehensive digital maturity model that integrates these dimensions into an integrated hierarchical framework. Their systematic review indicated that effective digital transformation requires a comprehensive assessment of maturity levels and the development of appropriate roadmaps for each stage (Aras & Büyüközkan, 2023). Similarly, Gokalp and Martinez (2021) proposed a Digital Transformation Capability Maturity Model (DX-CMM) specifically for industrial manufacturers, focusing on the balance between technical and organizational aspects. The model relies on standardized assessment methods such as SPICE levels to systematically guide improvements (Gokalp & Martinez, 2021).

In a simpler yet practical framework, Hagg and Sandhu (2017) proposed a three-level digital maturity model comprising awareness, expertise, and autonomy, emphasizing the

role of leadership and change management as key enablers for facilitating progress between these levels, particularly in large organizations (Hägg & Sandhu, 2017). Additionally, Schumacher (2016) designed a multidimensional model with nine dimensions to assess the readiness of manufacturing organizations for the transformation toward Industry 4.0. The model encompasses both technical and organizational aspects such as strategy, leadership, and culture. The study demonstrated the model's applicability in smart factory environments (Schumacher et al., 2016).

The concept of digital maturity has also been adapted to suit specific sectors, reflecting their specificities and challenges. For example, Wijnen (2020) presented a gradual digital maturity model for sports organizations, starting from analog and progressing to innovation, highlighting the importance of leadership and tailored strategies to foster digital adoption in this sector (Wijnen, 2020). Similarly, Kittkumpanat and colleagues (2023) developed an eight-dimensional digital maturity framework for sports media in Thailand, addressing culture, technology, organizational structure, customer engagement, strategy, operations, innovation, and data analytics, providing a nuanced and fundamental understanding of the level of digital readiness in this field (Kittkumpanat et al., 2023).

#### **1.8.4 Applications of AI in Construction Project**

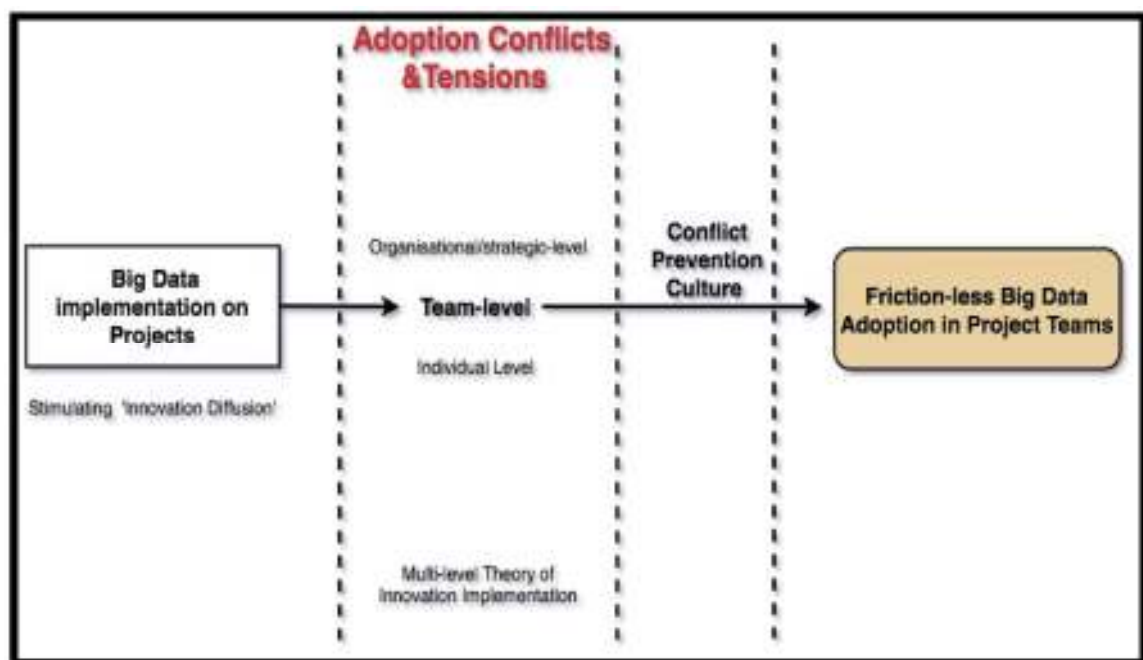
##### **1.8.4.1 Predictive Analytics**

Using a prototype to process- storing and analyzing- a huge database to fit a wide range of construction projects, Bilal et al. (2019) has developed a data-analytic approach to assess the profitability distribution in various construction projects. Here, data analysis showed that profit margins varied from time to time whereby that profitability performance is affected by various project parameters. To achieve a closer prediction accuracy, these findings are expected to integrate into a machine-learning algorithm. This approach has also modernized data analysis, uncovered the hidden patterns with regard to probability in various construction projects (Bilal et al., 2019). Being a valuable approach, the present study has explored the way the Agile methodology could be implemented in diverse environments. The research has therefore interviewed expertise project and big data managers. The interviews indicate the necessity to start with small scale implements, embrace minor setbacks as potentials for further constant improvements and adopt an interactive approach towards project development. Yet,

Challenges might appear when companies avoid or refuse applying cloud platforms or respond to solutions (Franková et al., 2016). With due regard to conflict management, Oyedele et al. (2020) examine the appropriate strategies of managing disagreements among teams in big database project companies. The present study, by contrast, insists the factors that could foster a culture of in-team-conflict-prevention. To achieve a conflict-free work environment, the researcher introduces four major factors; (i) effective-employees communication, (ii) team-competence in project management, (iii) proactive conflict management and (iv) effective project documentation. The study also introduces a framework of concepts aiming to improve human resource management through enhancing a conflict-proof environment of work so as to enable companies with big database opt for innovative as explained in figure (2) below (Oyedele et al., 2020).

**Figure 2**

*Big data innovation diffusion & the role of conflict in adoption*



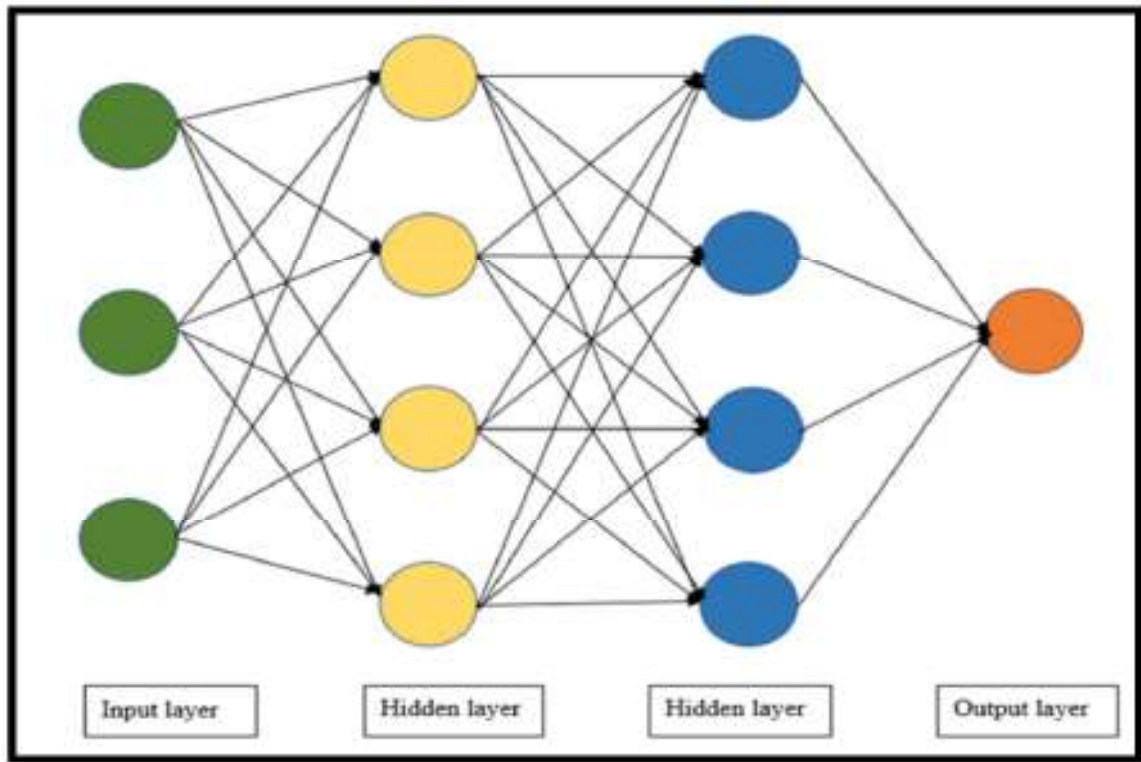
Source: Oyedele et al. (2020).

Likely, Azami et al (2022) has developed a framework of data analysis using crane configurations in huge industrial construction projects. The framework integrates heuristic search techniques with artificial neural network (ANN) optimization algorithms, as shown in Figure 3 below. While empirical studies help professionals identify appropriate crane configurations based on specific technical requirements, the ANN model leverages historical project data to refine the process of choice. To validate the model's accuracy and reliability, a K-fold cross-validation method was employed,

demonstrating that the model achieved an accuracy rate of up to 70% on the validation dataset (Azami et al., 2022).

**Figure 3**

*Neural network structure*



Source: Azami et al. (2022)

Aiming at identifying how predictive analytics can improve the accuracy of cost estimation during the initial phases of a project. Castro Miranda et al. (2022) have investigated the role of statistical analysis in early cost estimation in construction projects. Castro Miranda et al. (2022) finally primarily focused on the significance of (i) creating a large database, (ii) highlighting the cost-affecting factors and (iii) comparing between various methods of estimation. As a result, statistics indicates the high level that of accuracy that the analysis methodologies have gained, making them such eligible in practice. Castro Miranda et al. (2022) also explained three main aspects as; (i) cost prediction analyses were not perfectly consistent with methodologies' practices and standards, (ii) the productivity of analysis techniques is eligible to work well in the construction industry and (iii) such analytic methodology makes a model for executive administrators looking for adopting predictive analytics in cost estimation in deed, the enhancement of such tools is expected to enable stakeholders to have significant roles

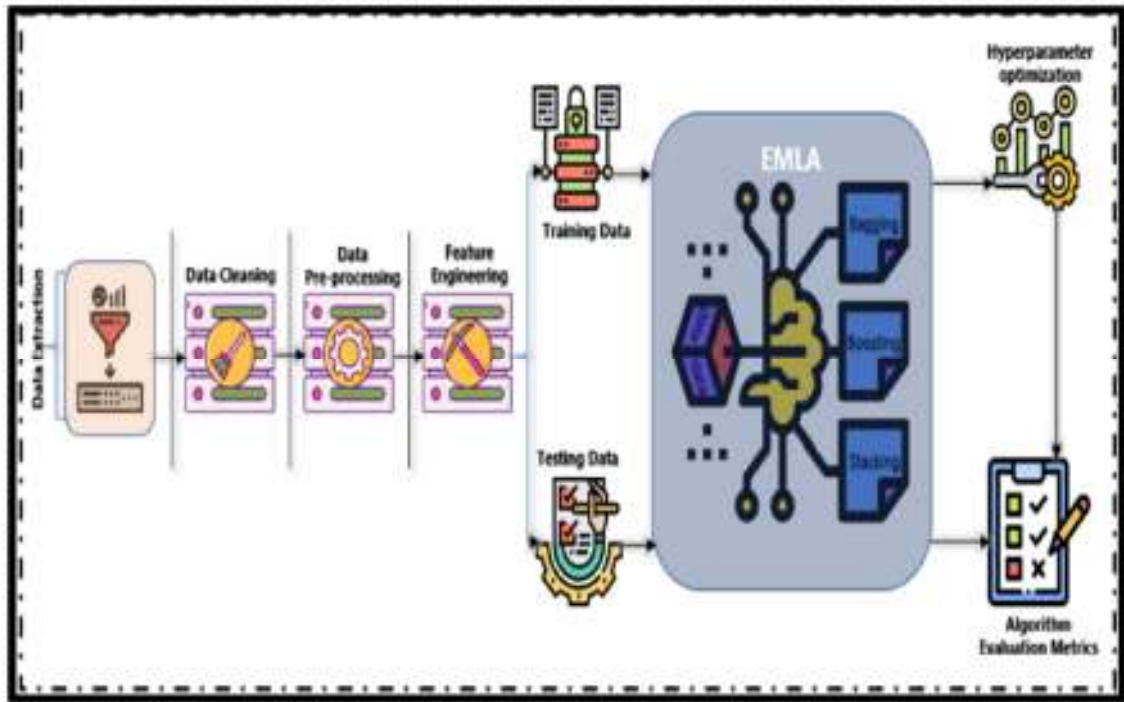
toward improving cost prediction accuracy, which contributes well to produce an efficient budget management (Castro Miranda et al., 2022). Furthermore, Bilal et al. (2019) presented a convex-mathematical-optimization based approach to coordinate spatial designs and identify basic plan alternatives. This approach has two mathematical models; (1) the convex relaxation model, w relying on acyclic graphs to build a basic set of relative constraints that define spatial relationships within the design, which helps in categorizing the structure of spaces, (2) the optimizing geometry space model in line with the size of the modules used in the design. This methodology relies on aspect ratio constraints to limit the creation of multiple layouts with large variations. To help users achieve the same functional goals, the algorithm cabanas produce an alternative basic plan model, more organized and integrated in structure. More importantly, some of these layouts promote more efficient waste management, contributing to a reduction of waste by 8.75% through reducing material shredding and improving space utilization (Bilal et al., 2019).

#### **1.8.4.2 Risk Mitigation**

In response to the troublesome construction projects delays that the construction sector faces, Egwim et al. (2021) have developed an advanced model with a set of ensemble machine learning algorithm (EMLA) - see figure (4) Below. Based on Bagging, Boosting, and Naïve Bayes techniques, the model selected the quantitative technique to improve a predictive model through hyper-parameter tuning (Egwim et al., 2021). This model actually uses various techniques for analysis including; Decision Tree, Random Forest and Bagging. Other techniques include performance boosting algorithms such as Adaptive Boosting Classification and Regression Tree (CART), Gradient Boosting Machines, and Extreme Gradient Boosting. In consequent, a model with really complicated and multi-layer and stacking-based predictive model has been achieved to enhance the performance and precision of the EMLA approach in predicting delays (Egwim et al., 2021).

**Figure 4**

*EMLA Prediction Architecture.*



Source: Egwim et al. (2021)

Examining the use of AI tools in the construction industry, K. Wang et al. (2023) has applied a fuzzy scenario environment using a framework of multi-criteria decision making (ACDM). This framework resembles aspects from Delphi method, the Analytic Network Process (ANP), and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Wang et al., 2023). Systematically, the ANP model aims to assess the significance of AI tools depending on the expatiates input e fuzzy TOPSIS categorizes the most appropriate AI solutions for the construction sector. It seems that the technological factors are most of significance while those of environment come next, though the two factors critically make the AI landscape in the world of construction (Wang et al., 2023). However, Okpala et al. (2020) have investigated the real implementations of technological tools and devices for risk reduction within the sector of construction with due regard to efficiently adopting, perceiving and the cost implication of the needed technologies. Practically, analysis of the use of those tools and devices offers valuable insights to help managers in the field of construction be well informed upon making decisions concerning safety performance (Okpala et al., 2020).

### **1.8.4.3 Cost Control during the Project**

Elmousalami (2021) has reviewed 20 artificial AI techniques already applied in conceptual cost modeling. The techniques include fuzzy logic, mathematical model, multiple regression, case-based reasoning, as well as hybrid models like the genetic fuzzy model. Others include the ensemble methods like XGBoost and that of the random forest. Towards assessing effectiveness and accuracy of machine learning logarithm in the prediction of project cost, these models have been tested using the field channel improvement projects (FCIPs) (Elmousalami, 2021). Consequently, basing on mean absolute percentage error (MAPE) findings showed that XGBoost with AMAPE of 9.091% and an adjusted  $R^2$  of 0.929 appeared to be the most accurate-reliable method (Elmousalami, 2021). The evaluation, based on mean absolute percentage error (MAPE) and adjusted  $R^2$ , revealed that XGBoost was the most accurate and reliable method, achieving a MAPE of 9.091% and an adjusted  $R^2$  of 0.929 (Elmousalami, 2021).

Furthermore, Xie et al (2022) experiments a combined AI and standard wireless communication method to traditionally test cost control after reviewing building's latest status beside the in the building materials (supplies) and the regulations and laws that actually regulate the surrounding environment and the construction process in general. Following experiments of the combined wireless-AI model, it has been that this model has gain success in both diction making in addition to the development of project cost management (Xie et al., 2022). in addition, applying the artificial neural networks (ANN) as suggested by (Omotayo et al., 2020) prepared the floor for the creation of a structured decision support technique for analyzing the most appropriate Prefabricated Construction Component Technologies (PCCTs) deployed in at variant stages of the construction process. Aside from demonstrating the efficacy of the emerging ANN-based decision support approach, the study's theoretical findings reveal that Critical Path Method (CPM) and Quantity Surveying (QS) professionals affect PCCTs selection decisions at different stages of the building process. Whereas Omotayo et al. (2020) QS professionals were mostly in charge of PCCT selection during the beginning and mid-level stages, CPM professionals were in charge of PCCT selection at the building process close-out phase. Elmousalami,(2020) Examine the most common methodologies and processes for identifying cost drivers, which have been classified into two categories in prior literature: quantitative and qualitative methods

(Elmousalami, 2020). In addition, the study investigates various computational intelligence (CI) techniques and combination approaches used in the construction of useful cost-predicting theories, as well as the combination of these methods in modeling and potential advances for expense modeling expansion, obstacles, and recommendations. Elmousalami (2020) examined the most widely used artificial intelligence (AI) techniques in cost modeling, such as fuzzy logic (FL), artificial neural networks (ANNs), case-based reasoning (CBR), decision trees (DT), random forests (RF), support vector machines (SVM), XGBoost, and genetic algorithms (GA). The analysis of 20 AI methods revealed that XGBoost was the most effective and reliable, with a mean absolute percentage error (MAPE) of 9.091% and an adjusted  $R^2$  value of 0.929 (Elmousalami, 2020). In a separate study, Cheng et al. (2009) have also employed AI techniques so as to predict the patterns of cash flow in construction companies. Here, the researchers aim to develop an effective management cash flow strategy using time margins, operation duration, construction space and resource requirements. They have employed a set of methodologies; like; K-means clustering, genetic algorithms (GA), fuzzy logic (FL) and the neural networks (NN). These were also used to make analysis of sequential cash flow patterns whereas the results of training were used to enhance strategic cash flow management. In that the S-curve has a direct impact on the performance of project management to control cash (Cheng et al., 2009).

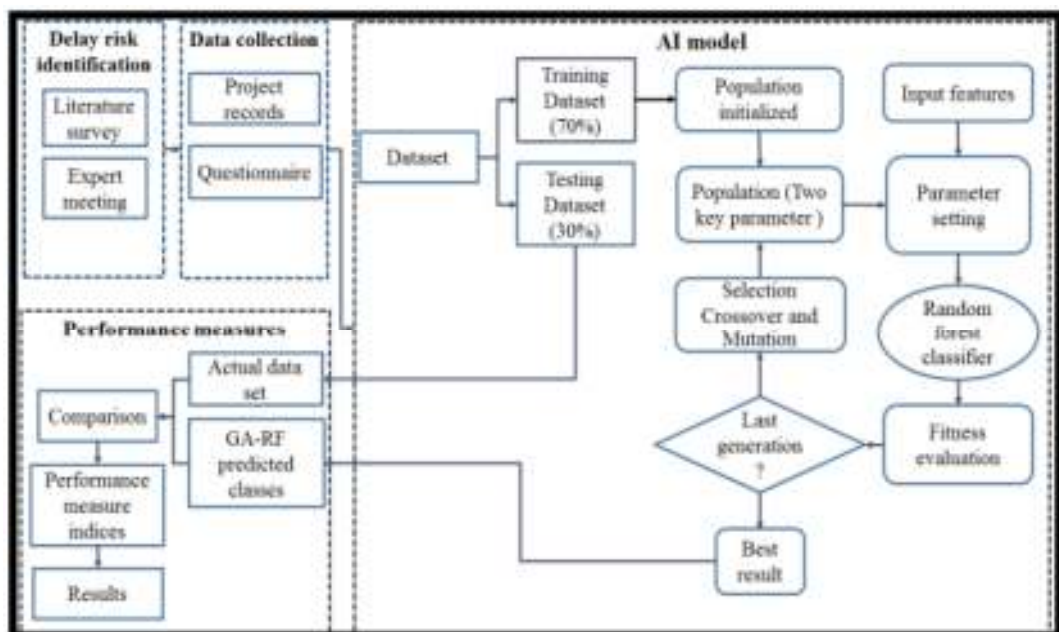
#### **1.8.4.4 Construction Site Assessment**

Abioye et al. (2021) have investigated the AI applications in the construction sector, aiming to assess the related methodologies, challenges and potentials, They have also shed light on the AI's effect on other construction concerns with regard to rather benefits of such technology (Abioye et al., 2021). Rampini & Re Cecconi (2022) have also explored the advantages of AI in managing the construction sector. To attain the research goals, the researchers reviewed 578 articles using bibliometric methods to identify leading institutions, prominent research topics, and relevant scientific journals (Rampini & Re Cecconi, 2022). Opting for quantitative analysis, and utilizing asset management (AM) and the AI technologies already implemented in these areas, they found that AI is widely applied in energy management, condition assessment, risk management, and project management (Rampini & Re Cecconi, 2022). future studies done by both academics and practitioners, including digital twins, generative adversarial

systems- synthetic images) for data augmentation, and deep learning for reinforcement. Having applied bibliometric and qualitative evaluation approach, Vein, Yin et al. (2019) similarly focused on the latest improvements in Building Information Modeling (BIM) for off-site construction (OSC). The researchers reviewed recent trends of research and identified knowledge gaps that might be possibly subjected to future research on BIM for OSC. It also contributed to the field by summarizing recent advancements and outlining the necessary research needs or further practice in the field of architecture, civil engineering, and construction (AEC) (Yin et al., 2019). Here, Patil (2019) has likely reviewed the use of AI in construction management, showing the significant role of such technology in fostering productivity in the construction sector (Patil, 2019). He focused on features of digitization in construction project management and the related sectors. Although this seems premature, comprehending the evolution of this topic, makes new room for further studies in the field (Patil, 2019). On the other hand, Yaseen et al. (2020) have developed a hybrid AI model for predicting project delays, labeled as Random Forest Classifier Integrated with Genetic Optimization Algorithm (RF-GA), (see Figure 5) below. In fact, This model resembles high performance in terms of classification accuracy at 91.67%, kappa value at 87%, and the error rate at 8.33%. 87%, and an error rate of 8.33% (Yaseen et al., 2020).

**Figure 5**

*Random Forest and Genetic Algorithm (RF-GA) structure*



Source: Yaseen et al. (2020)

Accordingly, considering control on construction projects with the due sustainability, this study's proposed technique indicates a high degree of efficiency as well as reliability in the construction project delays as suggested in (Yaseen et al., 2020). The latest attitudes in the engineering field indicate a growing awareness of back-end tasks though it is not preferable on the construction -site field tasks. As a result, typical risks and challenges mostly feature financial, legal, and social causes but not of interest in workers' physical safety regulations (Pillai & Matus, 2020).

## **Chapter Two**

### **Research Methodology**

Experimentally speaking, this chapter introduces the study's design with particular focus on data collection and processing, the construction company's sampling and the questionnaire's design.

#### **2.1 Overview**

To fill the research scarcity in the field of construction sector, this study explores the impact of digital transformation on the Palestinian construction companies' performance, particularly on the influence of digital information maturity. Such exploratory types of research usually aim to identify the scope of a case study or phenomena being investigated to clarify relevant factors or variables (Van Wyk, 2015). The researcher applied a bi-method approach to quantitative and qualitative data collection. According to Creswell(2014) this approach can provide more inclusive understanding of the research problem. Highlighting the present situation of digital transformation in the Palestinian construction companies, this study is conducted in six phases:

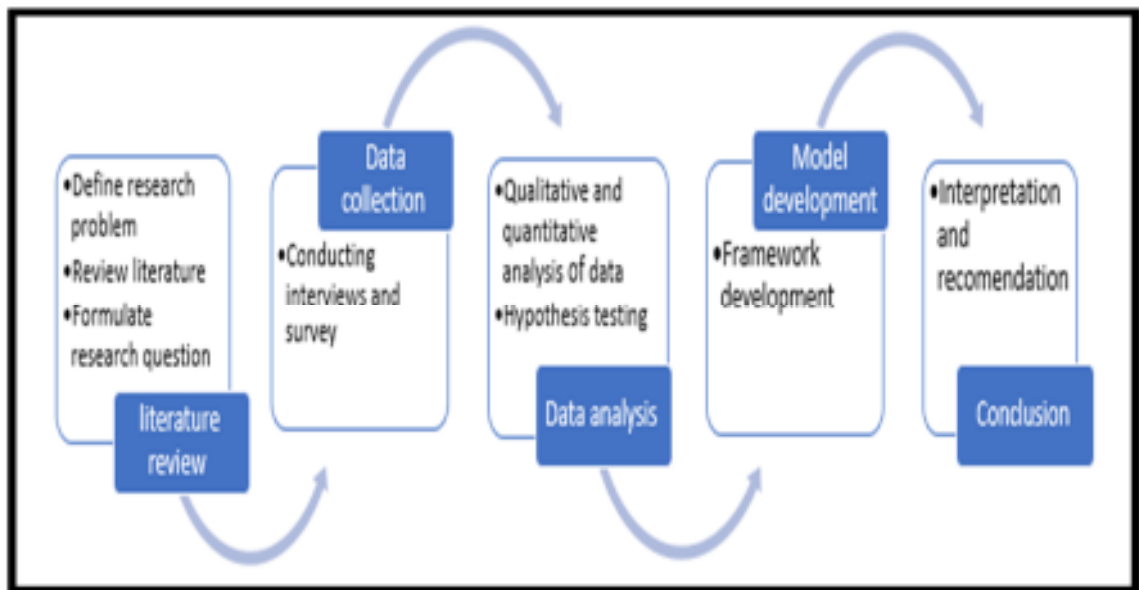
1. Stating and outlining the problem of the study, objectives, and scope.
2. Literature Review whereby the researcher reviews considerable previous academic research with due regard to this study's major trend, the influence of digital transformation in construction companies showing how previous researches addressed data collection and analysis.
3. Data Collection: here, the researcher has employed the following approaches:
  - Qualitative Approach: whereby the researcher, interviewed Palestinian construction companies' employees including; executives, officials, project managers, and field engineers. It is worth noting here that most of the interviews were done on the phone due to the security instability in Palestine.
  - Quantitative Approach: A questionnaire was designed based on a review of the literature and the results of the interviews.
- Data Analysis and Hypothesis Testing: Thematic analysis was used for the qualitative interviews (Braun & Clarke, 2006), while the questionnaire data was analyzed to test the relationships between the research variables.

- Developing the Theoretical Framework: A theoretical framework was developed to explain the relationship between digital transformation, project performance, and digital transformation maturity as an intervening factor.
- Drawing Conclusions and Recommendations: Proposals were presented to enhance digital transformation in the Palestinian construction sector.

The methodology followed in this research is summarized in the figure 6.

**Figure 6**

*Research methodology*



## 2.2 Target population and sampling procedure

The study population comprised construction companies operating in the West Bank, as classified by the Palestinian Contractors Union for the year 2024/2025. To ensure data accuracy, the Palestinian Ministry of Public Works, the General Union of Palestinian Contractors, and the Palestinian Engineers Association were contacted to obtain a list of registered and active construction companies. Based on the data collected, the total number of active and registered companies was 333, as detailed in Table 1.

**Table 1***Active Registered Construction Companies*

No.	Company classification	Population
1	First Classification	120
2	Second Classification	91
3	Third Classification	66
4	Fourth Classification	56
Total		333
Requested sample		143

Determining the minimum sample size is crucial in questionnaire-based studies and other statistical methods to ensure that the results can be generalized to the study population (SAUNDERS, 2014). This study determined the optimal sample size G\*Power program, following the variance-based Partial Least Squares Structural Equation Modeling (PLS-SEM) methodology. The calculations were based on the most complex variable regarding the number of independent variables predicting it. In this case, "digital transformation adoption" was identified as the most complex variable, as it is influenced by three independent variables: strategy, technology, and human resources.

Statistical power was analyzed using multiple linear regression analysis (fixed model, R<sup>2</sup> deviation from zero) Hair et al. (2019) based on the following criteria:

- Effect size: Small ( $f^2 = 0.02$ ), medium ( $f^2 = 0.15$ ), and large ( $f^2 = 0.35$ ).
- Statistical significance level:  $\alpha = 0.05$ .
- Statistical power:  $1 - \beta = 0.80$ .

The results indicated that a minimum sample size of 43 participants is required to detect a medium effect ( $f^2 = 0.15$ ), while a small effect ( $f^2 = 0.02$ ) requires 119 participants. The study targeted a minimum of 119 participants to ensure sufficient statistical power.

### **2.3 Questionnaire design**

For the sake of this study, the researcher has designed a questionnaire to test the study's hypotheses regarding digital transformation management, maturity of digital transformation and performance. Either of these hypotheses was assessed Liker's scale, namely, strong disagreement at scoring (1) or showing strong agreement upon scoring (5). The questionnaire's questions were built in correlation with previous studies' comprehensive reviews.

The questionnaire consists of four main sections:

Section One (6 paragraphs): addresses general information about the company and participants, including gender, company sector, number of employees, company classification, job position, and type of certificate.

Section Two (18 paragraphs): focuses on digital transformation management through three main axes, which are: the strategy followed, the technology used, and human resources policies. 6 paragraphs were allocated to each axis to measure its role in supporting digital transformation.

Section Three (6 paragraphs): measures the maturity of digital transformation in companies, through awareness of the importance of digital transformation, adoption of Building Information Modeling (BIM) technologies, integration of Internet of Things (IoT) technologies, adaptation to technological changes, updating strategies, and cybersecurity.

Section Four (24 items): Evaluates project performance across four dimensions: time performance, cost performance, project quality, and project scope, with five items for each dimension.

A group of experts reviewed the questionnaire to ensure the content validity and consistency of the questions. Their feedback regarding the length of the questionnaire, the wording of the questions, and the number of sentences were carefully considered and incorporated into the revisions. The final version of the questionnaire was initially written in English (see Appendix A). However, since the native language in Palestine is Arabic, the questionnaire was also translated into Arabic (see Appendix B) to ensure clarity and accessibility for all participants.

## 2.4 Qualitative Interviews

The qualitative phase of the research began with conducting semi-structured interviews involving representatives from companies within the construction sector. A total of 13 interviews were carried out with experts employed across nine companies, as detailed in Table (2). The participants comprised eight general managers, three project managers, and field engineers. To ensure precision in data collection and streamline the analysis process, all interviews were recorded using audio devices (Willis, 2015).

**Table 2**

*Characteristics of the companies and role of the interviewees*

NO	Company	Interviewee Job role	Experience (years)
1	Company A	General Manager	15
2	Company A	Project Manager	8
3	Company B	General Manager	23
4	Company C	Site Engineer	3
5	Company D	General Manager	17
6	Company D	Project Manager	12
7	Company E	General Manager	19
8	Company F	General Manager	16
9	Company F	Site Engineer	7
10	Company G	General Manager	21
11	Company H	Project Manager	9
12	Company I	General Manager	18
13	Company L	General Manager	22

The data in this study were analyzed using the thematic analysis approach, a straightforward method that facilitates the identification, examination, and reporting of patterns (themes) within qualitative data (Braun & Clarke, 2006).

## Chapter Three

### Data analysis and results

This chapter examines and presents the findings from quantitative data gathered through interviews and questionnaires. The initial section evaluates companies' preparedness for digital transformation and its influence on project performance, drawing on insights provided by industry experts during the interviews. Subsequently, the results of descriptive statistics and hypothesis testing, conducted using the PLS-SEM and SPSS programs, are discussed. The primary objective of this study is to assess the current level of readiness for digital transformation among construction companies in Palestine and to determine how this readiness impacts the overall efficiency of project performance.

#### 3.1 Interviews analysis

The primary objective of the study was to uncover key themes that reflect the current state of digital transformation within Palestinian companies. Additionally, it aimed to explore the effects of digital transformation on project performance in the construction sector. Based on the interview findings, the results were categorized into four central themes, as outlined below:

**First theme:** The role of current strategy, technology, and human resources in digital transformation:

Most respondents indicated the important role of current strategy, technology, and human resources policy in contributing to companies' transition to digital transformation in projects. Most respondents indicated that the current strategy, through a set of mechanisms aimed at improving operational efficiency, enhancing innovation, and investing in data analysis technologies to improve risk prediction and decision-making. Respondents also indicated that current technology is not just a tool, but a key enabler that helps companies achieve a comprehensive digital transformation in the construction sector. Companies can improve productivity, enhance sustainability, and excel in a competitive market by employing innovative technical solutions. As for the current human resources policy, Respondents indicated that it plays a vital role in supporting digital transformation in the construction sector, as it focuses on enhancing

competencies, building a supportive culture, developing flexible and comprehensive policies, and developing practices that contribute to the success of this transformation.

**Second theme:** Companies' readiness for digital transformation:

It aims to assess the construction companies' readiness for digital transformation, crucially needed to achieve progress in a world of rapid technological development. Respondents insisted that technology adoption contributes to achieving efficiency, reducing cost, and providing customers and society with much greater value. Nevertheless, some respondents talk about those difficulties that hinder the Palestinian construction sector from turning to full adoption of digitalization. The challenges are mostly of political, technical, economic, regularity, and social origins.

**Third theme:** Maturity of digital transformation:

Respondents indicated that digital transformation in construction companies in Palestine has made significant progress, but the level of maturity varies between companies due to factors such as financial resources and human competencies. Some respondents from leading construction indicated their companies turning to adopt using digitalization tools; like project management software and resource planning systems (ERP). Whereas smaller businesses struggle hard against challenging conditions. Responses from these businesses reflect slow development whereby technologies like Building Information Modeling (BIM) and cloud computing still fall in their immature stages of adoption. This mostly refers to a set of factors; lack of qualified personnel, high cost, and political instability. Traditional corporate culture in addition to restricted governmental efforts in this area. Yet, their considerable initiatives are witnessed from notch the private sector and some international MGOs.

**Fourth theme:** The Impact of Digital Transformation on Construction Project Performance:

This Theme focused on the respondents' opinions and expectations about the impact of digital transformation on construction project performance (time, cost, quality, and scope), where most respondents agreed that digital transformation contributes significantly to reducing time and improving operational efficiency. Using digital planning tools such as project management software allows for improved work scheduling and accurate monitoring while predicting and addressing risks.

While some technological tools like 3D modeling (NIM) can reduce errors and reworking, digital communication platforms are eligible to accelerate the process of information exchange and decision-making. In fact, the construction sector's adoption of modern technologies like 3D-printing and robotics helps to speed up the process of digital advanced transformation. AI besides advanced analytics can help attain more effective decision-making and better resource management, leading to achieving higher quality work and on-time project completion. According to most of the respondents, cost reduction leads to increased work efficiency. The use of Building Information Modeling (BIM) helps reduce errors and rework which means a real cost decrease. Using digital tools can also improve resource management accuracy through which wastes and expenses are reduced.

The immediate instant adoption of digitalizing the construction monitoring is expected to make a real reduction in the labor cost and long-term leases. Another technological tools like drones and sensors reduce much of the running and operational costs. In this regard, digital transformation offers solutions to have early risk analysis so that officers can properly manage the problems that arise and reduce financial loss in addition to improving asset maintenance for longer-life existence and reducing potential costs, in consequence. Respondents indicate how digital transformation actually contributes to reasonably improving the quality of construction projects through attaining accuracy and efficiency. This has enabled more detailed designs with better coordination between various disciplines. Whereas digital monitoring tools enable construction companies to ensure competent implementation of specifications and standards, AI could provide perfect analytics to improve the quality of decision-making. Here, projects can be virtually tested and visualized and tested with optional revising and adjusting before getting implemented in the real landscape. Moreover, digital communication platforms help make instant and accurate information with less error probability. These improvements have enabled construction companies to master the quality of service, and foster their competence to avoid project delays in response to customers' expectations. In conclusion, the respondents have shown that digital transformation has expanded the construction companies' scope of construction projects through mastering the eligibility to manage complicated operations with more efficient performance.

Other digital tools like Digital modeling (BIM) are used to coordinate between different project aspects, allowing work expansion without violating timetables or harming levels

of quality. Such tools can also make instant monitoring and right updating to manage to deal with rather larger and more complicated projects. Global implementations and coordination might be achieved through means of digitalization regardless of the geographical location. Integrating modern technologies like 3D printing and robotics for the enhancement of ambitious and promising projects would be another advantageous reflection of construction projects' that transform to digitalization. More importantly, advanced applications of data analysis offer flexibility towards planning and preferably redirecting various resources. In consequence, this makes it possible to implement larger types of projects efficiently.

### **3.2 Questionnaires analysis**

The relationship between digital transformation and construction project performance was examined using Smart PLS 3.2.7 and SPSS, both widely recognized tools for structural equation modeling (SEM) employing the partial least squares (PLS-SEM) approach. SEM is a multivariate analytical technique designed to assess causal relationships (Cho et al., 2009). SEM accordingly represents an effective pattern of prediction whereby small-sized samples or non-normal data distribution, Ali et al. (2018), are addressed with correlation to the nature of the study in hand which has consequently adopted the PLS-SEM-methodology for data analysis (Ali et al., 2018), This approach involves two key stages: (1) assessing the measurement model, which includes evaluating reliability and validity, and (2) analyzing the structural model, which entails testing hypotheses and identifying model parameters (Hair et al., 2019).

#### **3.2.1 Study population**

The data's demographic analysis showed that most respondents (72%) were males and 28% were females. The majority of companies were private joint-stock companies (44.1%), 38.5% were family companies, and 12.6% were public joint-stock companies. The percentage of companies with 5-9 employees was 32.2%, while the percentage of companies with 10-14 employees was 23.8%, and the percentage of companies with more than 25 employees was 16.1%. The demographic analysis also showed that the companies were classified according to the Palestinian Contractors Union, where 51.7% of the companies were classified as first-class companies. In comparison, 19.6% of the companies were classified as second-class companies, and the percentages of third and fourth-class companies were 14.7% and 7.7%, respectively. Most of the respondents

were site engineers and general managers (39.2% and 29.5%, respectively). Most respondents held a bachelor's degree (67.8%). Full details of the demographics of the respondents are summarized in Table 3.

**Table 3**

*Demographic characteristics of the study sample*

Variable	Group	N (%)
Gender	Male	103 (72)
	Female	40 (28)
	Total	143 (100)
Company classification by company type	Family Company	55 (38.5)
	Public Shareholding	18 (12.6)
	Private Shareholding	63 (44.1)
	Other	7 (4.9)
	Total	143 (100)
Number of employees in the company	5-9	46 (32.2)
	10-14	34 (23.8)
	15-19	29 (20.3)
	20-24	11 (7.7)
	≥25	23 (16.1)
	Total	143 (100)
Company classification with the Contractors Union	1st class	74 (51.7)
	2nd class	28 (19.6)
	3rd class	21 (14.7)
	4th class	11 (7.7)
	Other	9 (6.3)
	Total	143 (100)
Job	General Manager/CEO	37 (25.9)
	Administrative Director	19 (13.3)
	Project Manager	28 (19.6)
	Site Engineer	56 (39.2)
	Other	3 (2.1)
	Total	143 (100)
Educational degree	Diploma	6 (4.2)
	Bachelor's	97 (67.8)
	Master's	31 (21.7)
	PhD	9 (6.3)
	Total	143 (100)

## **1. Multivariate Analysis (MANOVA)**

Appendix C presents the outcomes of the Multivariate Analysis, highlighting the statistically significant differences in the levels of dependent variables influenced by the independent variables. The findings are summarized as follows:

- Gender: Statistically significant differences were observed across all dependent variables due to the impact of gender.
- Company Type: Significant variations were noted in all dependent variables based on the type of company.
- Number of Employees: The results demonstrated significant differences in all dependent variables influenced by the size of the workforce,
- Company Classification: Statistically significant differences were identified in all dependent variables due to the classification of the company.
- Job Position: Significant variations were found in all dependent variables based on the respondents' job positions.
- Academic Qualification: The analysis confirmed statistically significant differences in all dependent variables due to variations in academic qualifications.

### **3.2.2 Assessment of constructs implementation**

A general descriptive analysis was conducted to evaluate the level of ADT (Assessing Digital Transformation), which encompasses its key dimensions: strategy, technology, and human resources, in enabling digital transformation. Additionally, MP (Management Performance), reflecting the impact of digital transformation on construction project performance across its dimensions (time, cost, quality, and scope) was assessed. Furthermore, DM (Digital Maturity), was measured as a mediating factor in the relationship between digital transformation adoption and construction project management performance. A five-point Likert scale was utilized, where higher numerical values indicate greater importance, acceptance, and agreement, as illustrated in the table below:

**Table 4***Converting verbal answers according to the five-point Likert scale into numerical answers*

Scale	Degree				
Responses by words	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Responses by numbers	1	2	3	4	5

The responses were divided into five equal intervals to assess the response levels for the study items based on the established scale. These intervals were determined by dividing the total response range by the number of levels. Given that the study utilizes five levels, the following formula was applied:

$$\text{Interval length} = \frac{\text{Upper Value of response} - \text{Lower Value of response}}{5} = \frac{5 - 1}{5} = \frac{4}{5} = 0.8 \dots (1)$$

Accordingly, the rating table for the response degrees was created as a standard key, so that, it is relied upon to estimate the response scores, as follows:

**Table 5***Evaluating the means of response degrees*

Mean Interval	Degree Evaluation
1 → <1.80	Very low
1.80 → <2.60	Low
2.60 → <3.40	Moderate
3.40 → <4.20	High
4.20 → 5	Very high

Table 6 demonstrates the total level of effects and satisfaction in a descending order. The descending order of impact and satisfaction levels is shown, as the results indicate that the overall average of the levels of adoption of digital transformation (ADT), digitalization maturity (DM), and management performance (MP) were 3.73, 3.64, and 4.18, respectively, reflecting a high score in Palestinian companies. Regarding digital transformation adoption, the impact of technology was the most prominent with an average of 3.96, followed by the impact of both strategy and human resources, which recorded an equal average of 3.62. Digitalization maturity also showed a high level with an average of 3.64. As for management performance, the results showed that quality

performance recorded the highest level with a “very high” score with an average of 4.21, while cost performance was at the minimum with an average of 4.11, highlighting the disparity between the different performance dimensions.

**Table 6**  
*Levels of ADT, DM, and MP*

Construct	Mean	Standard deviation	Degree
Total degree of ADT			
(Adoption of digital transformation)	3.73	0.872	High
Impact of Technology	3.96	0.763	High
Impact of Strategy	3.62	1.032	High
Impact of Human Resources	3.62	0.956	High
Total degree of DM			
(Digitalization Maturity)	3.64	0.902	High
Total degree of MP			
(Management Performance)	4.18	0.613	High
Quality Performance	4.21	0.636	Very high
Scope	4.20	0.630	Very high
Time Performance	4.19	0.696	High
Cost Performance	4.11	0.697	High

### 3.2.3 Assessment of the measurement model

The measurement assessment model is significantly based on validity and measurement as major factors. According to Sekaran (2003), reliability is "the degree to which a measurement tool yields consistent results when applied to measure a specific concept," while validity refers to "the quality of the instrument's design and its capacity to measure the intended concept accurately" (Sekaran, 2003). previous studies have shown that evaluating reflective measurements models intends to test internal consistency, reliability, convergent validity and discriminant validity (Boudreau et al., 2001; Saunders et al., 2016). To evaluate reflective models, researchers ac typically rely on the criteria developed by (Götz et al., 2010; J. F. Hair et al., 2011a) to evaluate reflective models.

- The Role of Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is used to assess the relationships between indicators and their corresponding measurement constructs. Both reliability and validity are critical criteria for assessing reflective models (J. F. Hair et al., 2019). Whereas reliability is connected to the consistency of measurements, outcomes when the experiment is replicated under identical conditions, validity reflects the accuracy which enable instruments measure the concepts in discussion (Sekaran & Bougie, 2010).

- Evaluation criteria

Evaluation of reflective models includes checking:

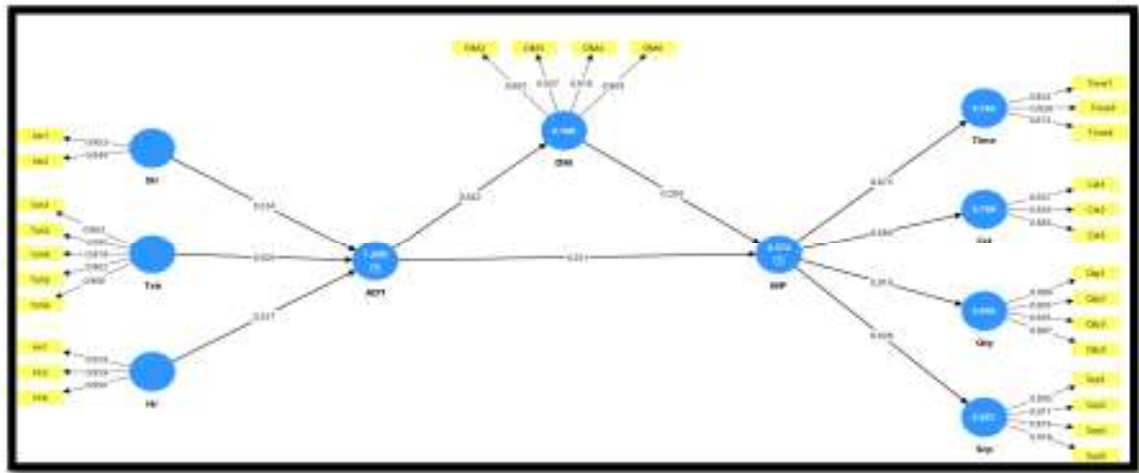
1. Internal Consistency. To evaluate internal consistency the researcher has applied both the Cronbach's Alpha and Composite Reliability (CR) which indicates strong reliability at (0.7.8) whereas d 0.7 scoring resemble acceptability in such exploratory research (Hair et al., 2011).
2. Convergent Validity. To assess the Convergent Validity, he researcher has opted for the Average Variance Extracted (AVE) testing, which confirms the validity conceptual construct upon exceeding a rate of (0.5) to confirm the validity of the conceptual construct (Hair et al., 2011).
3. Indicator Reliability. To assess the Convergent Validity, he item loading test through indicating the contribution of either item to the conceptual construct. Here, item loading is expected to exceed a value of (0.7) (J. F. Hair et al., 2019). In fact, the present study item loading ranges between 0.756 to 0.957, demonstrating satisfactory indicator reliability.

- Main Results

The measurement model was assessed using SmartPLS 4. The outer loadings for all reflective indicators were determined as shown in Figure 7. Outer loadings ranged from 0.854 to 0.953, exceeding the recommended threshold of 0.70, indicating satisfactory indicator reliability. Table (7) below shows that the achieved construct indicates reliability indicators with CR, internal consistency at a satisfying level, it demonstrates that the selected items are effective in measuring the three main dimensions (strategy, technology, human resources) in addition to performance and maturity.

**Figure 7**

*The results of PLS -algorithm for research model*



- Validity Analysis

The researcher has examined convergent validity through testing positive relationships between a construct's alternative indicators, while discriminant validity is tested on comparisons with different variables. Here, the calculation of the Average Variance Extracted (AVE) confirmed that the model assures the convergent validity condition, with all values surpassing (0.5). Such findings demonstrate that the reflective model exhibits strong validity and reliability, also confirmed in the internal consistency, indicator reliability, and both convergent and discriminant validity. This also indicated the validity of the assessment procedure implemented.

**Table 7**

*Results of reliability and validity analysis*

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Cst	0.903	0.905	0.940	0.838
DM	0.935	0.937	0.954	0.838
Hr	0.933	0.934	0.958	0.883
MP	0.925	0.928	0.947	0.816
Qty	0.927	0.927	0.948	0.821
Scp	0.921	0.923	0.944	0.809
Str	0.894	0.895	0.950	0.904
Tch	0.932	0.933	0.948	0.785
Time	0.861	0.862	0.915	0.783

Table (7) above has shown that all (AVE) constructs confirm validity via exceeding the minimum value of (0.5). it also indicates that variant contract indicator really contributes to each other's.

- Convergent Validity:

Discriminant validity is defined by Hair et al., (2014) as the ability of standardized instruments to differentiate between different constructs or measure disparate concepts. In contrast to convergent validity, discriminant validity assesses each measure based on its independent properties (Campbell & Fiske, 1959). This validity plays a crucial role in ensuring that research instruments do not measure unexpected or irrelevant items (Urbach&Ahlemann, 2010).

Two primary methods are employed to assess discriminant validity: cross-loading (Chin, 1998) and (Fornell & Larcker, 1981). According to Hair et al. (2011), discriminant validity is established when the average variance extracted (AVE) for each latent construct exceeds its highest squared correlation coefficient with other latent constructs (Hair et al., 2011), as per the Fornell-Larcker (1981). Additionally, indicator loadings must be greater than any cross-loadings to ensure the validity of the measurement. This study evaluated discriminant validity using the Fornell-Larcker Criterion (Fornell & Larcker, 1981).

As illustrated in Table 8, the diagonal values in the correlation matrix represent the square root of the average variance extracted (AVE) for each latent construct. Discriminant validity is achieved when the diagonal values surpass the non-diagonal values within the matrix, a condition reflected in the correlation matrix results, thereby enhancing the reliability of the study's discriminant validity.

Additionally, the correlation matrix of the independent variables was examined to identify any indications of strong associations between them. Multicollinearity occurs when the correlation coefficient between the independent variables exceeds 0.9, according to both Hair et al. (2010) and Pallant (2016). Conversely, Pallant (2016) suggests that a correlation coefficient higher than 0.7 may indicate the presence of multicollinearity (Hair et al., 2010; Pallant, 2016).

Moreover, discriminant validity was verified using the heterotrait-monotrait ratio (HTMT) (Henseler et al., 2015). As shown in Table 9, all HTMT values were below the most conservative threshold of 0.85, indicating no strong associations between the external factors. The results confirmed that all correlation values were well below this threshold, indicating no issues related to multicollinearity and reinforcing the quality of the study's discriminant validity.

**Table 8**

*Discriminant validity check (square root of AVE is shown on the diagonal in bold) based on Fornell-Larcker criterion method*

	Cst	DM	Hr	Qty	Scp	Str	Tch	Time
ADT								
Cst	<b>0.916</b>							
DM	0.522	<b>0.915</b>						
Hr	0.397	0.809	<b>0.939</b>					
Qty	0.737	0.583	0.5	<b>0.906</b>				
Scp	0.746	0.503	0.455	0.823	<b>0.9</b>			
Str	0.391	0.782	0.803	0.456	0.387	<b>0.951</b>		
Tch	0.543	0.781	0.829	0.606	0.575	0.788	<b>0.886</b>	
Time	0.774	0.473	0.415	0.706	0.743	0.412	0.569	<b>0.885</b>

**Table 9**

*Discriminant validity check using HTMT*

	Cst	DM	Hr	Qty	Scp	Str	Tch	Time
Cst								
DM	0.569							
Hr	0.432	0.865						
Qty	0.804	0.627	0.536					
Scp	0.814	0.54	0.489	0.89				
Str	0.434	0.853	0.879	0.499	0.423			
Tch	0.593	0.832	0.887	0.652	0.619	0.861		
Time	0.876	0.528	0.465	0.791	0.831	0.468	0.638	

- The Variance Inflationfactor (VIF)

Based on the disjoint two-stage approach, the assessment of the formative second-order construct ADT demonstrates satisfactory measurement properties. The outer weights indicate that the Impact of Technology (Tch) (0.623) makes the strongest contribution to ADT, followed by the Impact of Human Resources (Hr) (0.257) and the Impact of Strategy (Str) (0.178). All first-order constructs exhibit high outer loadings—0.875 for Str, 0.977 for Tch, and 0.917 for Hr—exceeding the recommended threshold of 0.70 (Sarstedt et al., 2021), confirming strong indicator reliability. Moreover, the VIF values (3.697 for Tch and 3.942 for Hr) are well below the conservative cut-off of 5 (Sarstedt et al., 2021), indicating the absence of multicollinearity issues among the indicators. These results collectively support the validity of the ADT construct as a second-order formative construct.

**Table 10**

*Assessment of formative constructs.*

Second -order construct	First -order construct	Outer weights	Outer loadings	VIF
ADT	Impact of Strategy (Str)	0.178	0.875	3.25
	Impact of Technology (Tch)	0.623	0.977	3.697
	Impact of Human Resources (Hr)	0.257	0.917	3.942

- Model fit

The model fit indices indicate that the proposed model demonstrates an excellent fit to the data. The SRMR value is 0.049, which is below the commonly recommended threshold of 0.08 (Hu & Bentler, 2009). The Chi-square statistic (144.160) is reported alongside a high NFI value of 0.910, which exceeds the recommended cut-off of 0.90 (Bentler & Bonett, 1980; Sarstedt et al., 2021)., further confirming the adequacy of the model. Overall, these results provide strong evidence that the structural model fits the data well. Appendix D show the model fit

### 3.2.4 Assessment of the structural model

PLS analysis was employed to evaluate the internal structure of the model, following the criteria established by Hair et al. (2011), Hair, Jr et al. (2013), and Fernandes (2012). This evaluation encompassed an analysis of R<sup>2</sup> values, effect size (f<sup>2</sup>), the predictive significance of the model, and goodness of fit (GoF) (Fernandes, 2012; Hair, Jr et al., 2013; J. F. Hair et al., 2011). Finally, the study has examined the magnitude and significance coefficients. These have been retested for the sake of the study hypotheses validity.

#### 3.2.4.1 The determination coefficient (R<sup>2</sup>)

Hair et al. (2011) introduce several criteria for the (PLS-SEM) model assessment, including; (i) coefficients of determination (R<sup>2</sup>), (ii) as well as the significance and (iii) magnitude of the path coefficients, besides the effect size (f<sup>2</sup>), predictive significance (Q<sup>2</sup>), and effect size (q<sup>2</sup>). The criteria represent the accuracy of the path model in PLS at a high level of the addressed constructs' (R<sup>2</sup>). Grading R<sup>2</sup> into 'high' level depends on the field of research; while an (R<sup>2</sup>) of (0.75) indicates a high explanatory power, (R<sup>2</sup>) at (0.20) seems high with due regard to customer behavior (Hair et al., 2011). Yet, in marketing research, R<sup>2</sup> values are classified into; 0.75 = Strong effect, 0.50 = Medium effect, and 0.25 = Weak effect (J. F. Hair et al., 2019).

Consequently, this indicates the significance of (R<sup>2</sup>) as a fundamental indicator for measuring the extent to which external variables explain the variance in the endogenous variables, being also vital the quality of the structural model assessment. Appendix E shows that the R<sup>2</sup> value for the MP variable at 0.695, indicating a high level of explanation. It means the ADT and DM variables explain 69.5% of the variance in MP.

#### 3.2.4.2 The determination coefficient (R<sup>2</sup>)

The effect size analysis (f<sup>2</sup>) vitally estimate the amount of influence t latent variable has one the dependent ones (Chin & Newsted, 1998). the following formally is actually used to estimate the value (f<sup>2</sup>) as PLS analysis does not automatically compute it:

$$\text{Effect size: } f^2 = \frac{R_{include}^2 - R_{exclude}^2}{1 - R_{include}^2} \dots\dots\dots (2)$$

This type of analysis followed Cohen's(1988) model of manual calculation whereby ( $f^2$ ) values' size effects are categorized into either small at 0.02, medium at 0.15 or large at 0.35 predictive variables (Cohen, 1988). So, the present study can apply such model to evaluate the role interactive variables in addition to utilizing this approach in PLS analysis (Landau & Bock, 2013). For testing the model and having an accurate understanding the effect of of interactive factors on structural relationships, Hair et al. (2013) and Henseler & Fassott (2010) have recommended turning main effects into simple or single ones see(Hair, Jr et al., 2013; Henseler & Fassott, 2010). As shown in Appendix E, the  $f^2$  values for both ADT and DM in explaining the endogenous variable MP were 0.079 and 0.030, respectively, indicating that the effect size of ADT and DM on MP is classified as large.

### 3.2.4.3 Predictive Relevance of the Model

Assessing the strength of a structural model is a fundamental process that involves using a “blindfold” technique to create an iterative cross-validation measure  $Q^2$ , in parallel with analyzing the coefficients of determination  $R^2$  and effect sizes. According to Hair et al. (2011), assessing  $Q^2$  for both structural and standard models requires predicting the data using PLS-SEM estimates, which is consistent with the methodology adopted for this analysis(Hair et al., 2011). A  $Q^2$  measure greater than zero for any endogenous latent variable indicates high explanatory power for that variable. The  $Q^2$  measure is utilized to assess how effectively the model predicts data that were not included in the estimation process, a concept known as predictive relevance (Hair, Jr et al., 2013). According to Fernandes (2012), the Stone-Geiser test is calculated using the following equation:

$$Q^2 = 1 - SSE/SSO \dots\dots\dots (3)$$

It is important to note that the blindfolding technique is considered appropriate when the target latent variables consist of reflective indicators (J. F. Hair et al., 2011; Henseler et al., 2009). Bagozzi (1994) explained that a positive  $Q^2$  value indicates that the model has predictive relevance, while negative values suggest a lack of predictive ability (Bagozzi, 1994). Appendix E shows that the  $Q^2$  values for MP and DM were (0.349) and (0.682), respectively, approving the model's strong predictive fitting.

### 3.3 Testing of Hypotheses

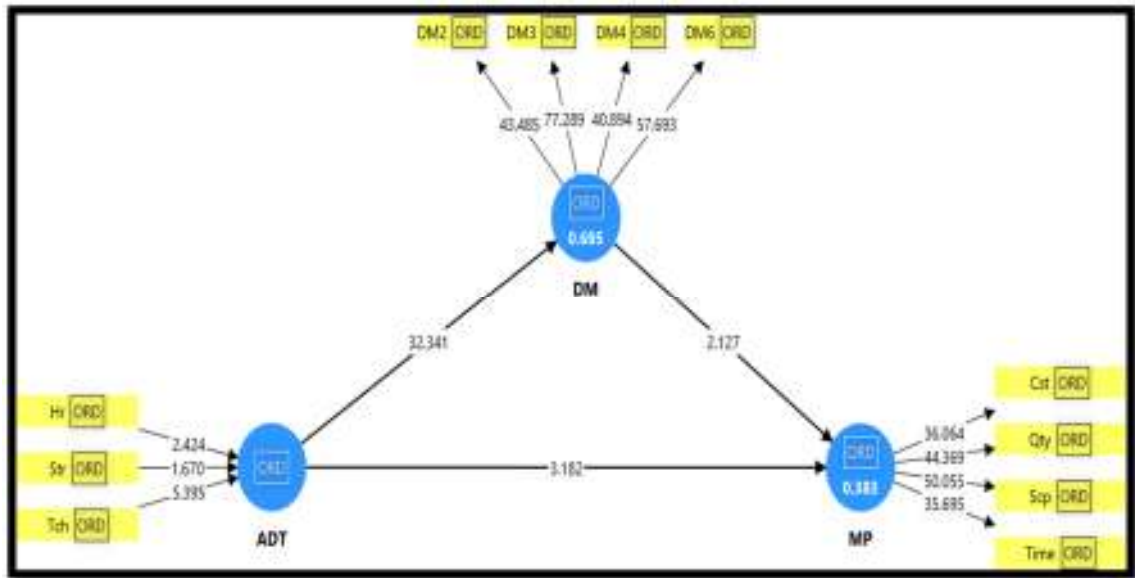
The present study aims to examine the effect of ADT practices on the MP four dimensions, with regard mediating role of DM. So, to determine the strength of the relationships between the latent variables, the standardized path coefficients ( $\beta$ ), they applied the PLS algorithm with a default setting of 300 iterations using factor analysis as a weighting method. Ranging between (-1- +1),  $\beta$  values in coefficient get even stronger when approaching ( $\pm 1$ ) (J. F. Hair et al., 2019). Figure (8) illustrates the t-value was determined through the bootstrapping procedure hypotheses and assess the significance of variables relations, the t-value was determined through bootstrapping procedure with a default setting of 500 subsamples. here, a relationship becomes such significant on statistic if the t-value signs 1.96 at 5% significant level while the P-value is less than 0.05. see figure (8) and Appendix F.

The results demonstrated that ADT practices have a positive and statistically significant effect on MP, with values of  $\beta = 0.399$ ,  $t = 3.182$ , and  $p = 0.001$ , supporting hypothesis H1. These findings align with the results of studies by Naji et al. (2024) and Dolla et al. (2023). The analysis also revealed a statistically significant positive relationship between ADT and DM, with values of  $\beta = 0.834$ ,  $t = 32.341$ , and  $p = 0.00$ , supporting hypothesis H2. This is consistent with the findings of Wernicke et al. (2023), who confirmed the existence of a positive relationship between ADT and DM.

Additionally, a statistically significant positive effect was found between DM and MP, with values of  $\beta = 0.399$ ,  $t = 3.182$ , and  $p = 0.001$ , supporting hypothesis H3. These results are in line with the study by Wernicke et al. (2023), which indicated that DM positively influences the performance of construction projects.

**Figure 8**

*PLS Bootstrapping (T-values) for the research model*



### Mediating test

DM serves as a variable of mediating between ADT and MP contributing to formulate hypothesis H4. As for methodology, the researcher has adopted the model of Preacher and Hayes (2008), which accordingly distinguish between direct and indirect effects (Preacher & Hayes, 2008).

Analysis has revealed that ADT's direct effect on MP, excluding mediating variables, is statistically significant with the values as  $\beta = 0.399$ ,  $t = 3.182$ , and  $p = 0.001$ . Upon including mediating variables, the effect of ADT on MP becomes like;  $\beta = 0.604$ ,  $t = 10.911$ , and  $p = 0.000$  reflecting that the mediating variables have considerable effect of ADT on MP.

Regarding the indirect effect (ADT  $\rightarrow$  DM  $\rightarrow$  MP), analysis has shown statistical significance, with values of  $\beta = 0.205$ ,  $t = 2.110$ , and  $p = 0.035$ . To determine the extent of such effect, Hair et al. (2019) has recommended calculating the variants (VAF) ratio, which measures the proportion of the indirect effect (Hair et al., 2019). Yet, this study has revealed that the VAF, falling between 20%-80% is 54.55 to indicate partial mediation according to the criteria of Hair et al. (2019). Accordingly, it is evident that DM partially mediates the relationship between ADT and MP, thereby supporting hypothesis H4.

## **Chapter Four**

### **Discussion and conclusions**

#### **4.1 Chapter overview**

This chapter discusses the present study's findings and data analysis including descriptive statistics, hypotheses testing, and interviews. It has two sections whereby: the first examines the role of digital transformation in the construction projects' performance with due regard to the effective factors; of strategy, technology, and human resources, and the second summarizes the main findings and conclusions of the study.

#### **4.2 Discussion**

This present study examines the roles of strategy, technology, and human resources in the process of digital transformation, as well as the impact of such transformation maturity on the performance of the Palestinian construction sector. For a more efficient and deeper understanding of the factors influencing digital transformation, the study also explores the extent to which digital transformation management is implemented and how it may contribute to improving project performance.

Accordingly, the results have revealed that the proposed strategy contributes to supporting digital transformation, which corresponds well with the findings of Dolla et al. (2023), indicating that project management principles remain constant. Yet, they get modified upon practice with the adoption of Industrial (4.0) Revolution technologies in the construction sector, highlighting the significance of stakeholder engagement in the process of re-engineering, training, and creating unified data, with respect to the size of a company. The results finally emphasize the necessity to adopt a long-term strategy for digital transformation, recommending multidisciplinary teamwork and taking the required training programs into account (Dolla et al., 2023). The results also correlate with the findings of Naji et al. (2024), who indicated that the strategy directs digital transformation in the construction sector by improving planning and design, fostering decision-making, and the system's comprehensive diagnosis. It also facilitates collaboration between stakeholders and enhances project delivery and asset management utilizing the available technology. The digital transformation readiness framework also provides tools to assess and develop smart strategies that enhance innovation and efficiency (Naji et al., 2024). The results also seem consistent with

Ernstsen et al. (2021) who insight, who assert that strategies play a pivotal role in improving construction sector performance by fostering innovation. The visions of innovation leaders point to a future driven by digital technologies, characterized by efficient construction processes, user-driven built environments, and value-based computational design. The study also emphasizes the role of technology in transforming the design of structures, methods of collaboration, and standards of design, thereby supporting both profitable and societal advancements in the construction sector. (Ernstsen et al., 2021). Accordingly, hypothesis H1 was supported.

In the second section of the first hypothesis, researchers Adeloje et al. (2023) The role of technology in digital transformation is pivotal, particularly in the construction sector. Technology is a key driver, with AI playing a central role in enhancing productivity. AI achieves this by leveraging big data and integrating emerging digital technologies such as computer vision, robotics, and machine learning (Adeloje et al., 2023). The study classified AI technologies into emerging and mature fields, noting the challenges that hinder their adoption, such as the shortcomings of using deep learning. It also provided recommendations to help researchers and decision-makers improve AI applications and reduce their associated risks. Moreover, BIM, Virtual and Augmented Reality (VR/AR), drones, 3D printing, robotics, digital twins, and IoT significantly enhance pre-construction, construction, and facility management processes (Naji et al., 2024). While laws and policies play a crucial role in adopting these technologies, their integration often faces challenges, including resistance to change and poor system integration. The study provides insights on how to accelerate digital transformation through successful examples, along with proposals to analyze the economic, social, and environmental impacts of technology (Naji et al., 2024), supporting the role of technology in hypothesis H1.

As for the third and final section of the first hypothesis, related to the role of human resources in contributing to digital transformation, the results of Purwanto et al.'s research confirmed (2023) the importance of this role, as he explained that human resources play a fundamental role in achieving digital transformation in construction projects by qualifying the workforce to keep pace with digital changes through training and development, managing change to facilitate the acceptance of new technology, and attracting qualified technical competencies to implement digital strategies. Human

resources also improve efficiency and productivity by integrating technology into daily operations and using data analysis tools to support strategic decision-making and enhance competitive advantage (Purwanto et al., 2023). The researchers Dolla et al. (2023) pointed out that human resources contribute to leading the digital transformation in construction projects by enhancing workers' skills with modern technology and facilitating institutional change to ensure the efficient adoption of digital systems. Digital transformation can also coordinate between various parties to modify the process for integration and innovation utilizing data to improving decision-making and achieve smart transformation in the construction industry (4.0) (Dolla et al., 2023). Here, the findings of Dolla et al (2023), actually support this study's H1 with regard to the contribution of strategy, technology, and human resources to digital transformation in the construction sector.

Digital transformation maturity is significant for enhancing efficiency and driving progress in construction companies. In that, Jäkel et al. (2024) demonstrate that maturity models offer a comprehensive framework for assessing the level of digitalization in various companies. These models contribute to improving internal operations and boosting productivity by adopting advanced technologies; like AI and the IoT. This approach not only enhances the quality of implementation but also ensures that digital infrastructure aligns with business requirements (Jäkel et al., 2024). Similarly, Naji et al. (2024) emphasize that digital transformation maturity helps achieve innovation and operational efficiency in different industries. The adoption of modern technologies- AI, IoT, and BIM, leads to better data management, reduces errors, and enhances collaboration among stakeholders (Naji et al., 2024). It likely contributes to overcoming the challenges that arise due to industrial fragmentation in an integrated digital environment that supports strategic instant and efficient decision-making. In addition, digital transformation enhances projects' sustainability and flexibility, as it relies on an advanced digital infrastructure contributing to better productivity and effectively dealing with future challenges (Naji et al., 2024). Wernicke et al, (2023), also indicate that the maturity of digital transformation can positively affect project performance by improving operational efficiency, reducing errors, and enhancing process productivity. It also contributes to improving planning and resource management and increases collaboration between stakeholders, leading to more accurate and faster decisions. Moreover, digital transformation supports achieving project sustainability by improving

quality management and reducing environmental impact, while providing potential for organizational growth via adopting technological innovation and leveraging data (Wernicke et al., 2023). Accordingly, the findings of these studies support the present study's results, mainly the hypotheses H2 and H3.

The present study results have shown a relationship between the impact of digital transformation maturity and of that on project performance. In this sense, Navon (2005), explains that digital transformation in construction projects accelerates data collection and processing, reducing the time required to identify a problem and provide a solution. Digital systems can actually contribute to helping digitalization take over from manual methods, increase efficiency and accuracy, and enable real-time performance monitoring. This might develop time management and reduce the chances of project delays (Navon, 2005). Likewise, Egwim et al. (2021) stated that digital transformation in construction projects, with the use of AI technologies, improves time performance through process automation and data analysis. These might all contribute to accelerated planning and implementation. It also vitally helps avoid risk management, consider potential risks, provide early warnings, and enable proactive decision-making, which can in consequence reduce delays and improve project efficiency (Egwim et al., 2021). Such previous studies supported the first part of the present H4. This refers to the positive impact of digital transformation maturity on the time performance in construction projects.

Xie et al. (2022) pointed out that the maturity of digital transformation positively affects cost performance in construction projects through improving estimation and cost control processes using AI and wireless networks of communication. This accordingly enables reductions in material waste and labor costs leading to the right decision-making based on real-time data analysis. Digital transformation can also reduce material waste, and labor costs and help make real-time decisions on data analysis in addition to making the spending efficient and ensuring the potential for sustainable profitability (Xie et al., 2022). Omotayo et al. (2020) also demonstrate that digital transformation maturity supports project cost control by improving processes and reducing inefficiency using intelligent technologies such as artificial neural networks. The focus here insists on monitoring material and equipment costs in the early stages, using historical data and cost predictions in the intermediate stages, and enhancing the role of project managers

in the final stages to assess deviations. Digital maturity contributes to making accurate decisions and achieving better financial results (Omotayo et al., 2020). (Omotayo et al., 2020) findings correlate to the results of the present study, particularly the second part of the H4, showing a positive relationship between digital transformation maturity and cost performance in construction projects.

Naji et al. (2024) have indicated that the maturity of digital transformation has a significant positive impact on the quality of projects in the construction sector, during the implementation phase in particular. It improves process integration, reduces errors, and increases efficiency and productivity. Digital transformation can also enhance the ability to detect risks early, and facilitate cooperation between project stakeholders through tools such as (BIM) and (IoT), which help improve the quality of construction projects (Naji et al, 2024). However, Shaban et al. (2024) believe that the maturity of digital transformation in construction projects crucially contributes to increasing the quality of projects by simplifying processes and enhancing transparency among the parties involved. This impact is clearly reflected in improving quality management through integration (BIM) and cloud computing, a matter that enables immediate process monitoring, and documentation of defects and solutions. In addition, these technologies adoption help reduce errors and rework, which saves both time and resources, which would positively affect the efficiency of implementation and accuracy of results (Shaban et al., 2024). The results of the present study supported H4 which states that there is a positive relationship between digital transformation maturity and quality performance in construction projects.

In general, digital transformation maturity expands the scope of projects by improving collaboration and integration between parties via digital tools, enabling synchronized management for better planning and reduced waste. Yet, this enhances flexibility in dealing with changes to effectively achieve project objectives (Dolla et al., 2023). Digital transformation maturity has also become a major factor in the performance of construction projects. Adopting digital technologies can enhance operational efficiency, reduce costs, enhance safety, and focus on increasing sustainability. Digital transformation also enables companies to address labor shortages and skills gap challenges by automating repetitive tasks and enhancing workforce capabilities (Cao et al., 2023). This supports the final part of the present study's H4, stating a positive

relationship between digital transformation maturity and construction project performance.

### **4.3 Conclusions**

The present study has shown that the Palestinian construction companies aim to achieve sustainable and exceptional operational performance. The study originally investigates how digital transformation influences the performance of construction projects through multiple dimensions, emphasizing the mediating role of digital maturity in the relationship between these variables. Accordingly the study has reveal that technology, strategic planning, and human resources critically and positively drive digital transformation and impacting project outcomes, utilizing a conceptual framework. Here are the four hypotheses formulated and tested through partial least squares structural equation modeling (PLS-SEM). Finally, such analysis underscores the substantial influence of digital transformation on enhancing project timelines, cost efficiency, and quality, while also demonstrating that digital maturity partially mediates this relationship. The study further validates the necessity of establishing well-defined digital transformation strategies and integrating advanced technologies within the Palestinian construction industry. Consequently, the successful execution of digital transformation initiatives, coupled with increased digital maturity, significantly enhances overall project performance.

## **Chapter Five**

### **Strategy of Digitalization in Construction Sector Framework**

#### **5.1 Chapter overview**

In accordance with the post analysis findings, this chapter the model that the researcher as adopted throughout the study. it is framework that provide construction projects decision makers with guidelines regarding digitalization in the construction sector. Tis actually can help managers there to enhance their strategies and operations achieve the potential objectives properly well.

#### **5.2 Model development**

Digital transformation - an integration of modern technologies to improve both performance and productivity - has rapidly and vitally become part of various sectors including that of construction. This model aims at achieving cooperation among major Palestinian construction sector's stakeholders, namely; construction companies, supervision offices, the Palestinian Engineers Association, the Palestinian construction Union, supporting institutions and partners in addition to the government related ministries. Within this range of collaboration, the parties can strengthen their relations towards the achievement of more efficient implementations.

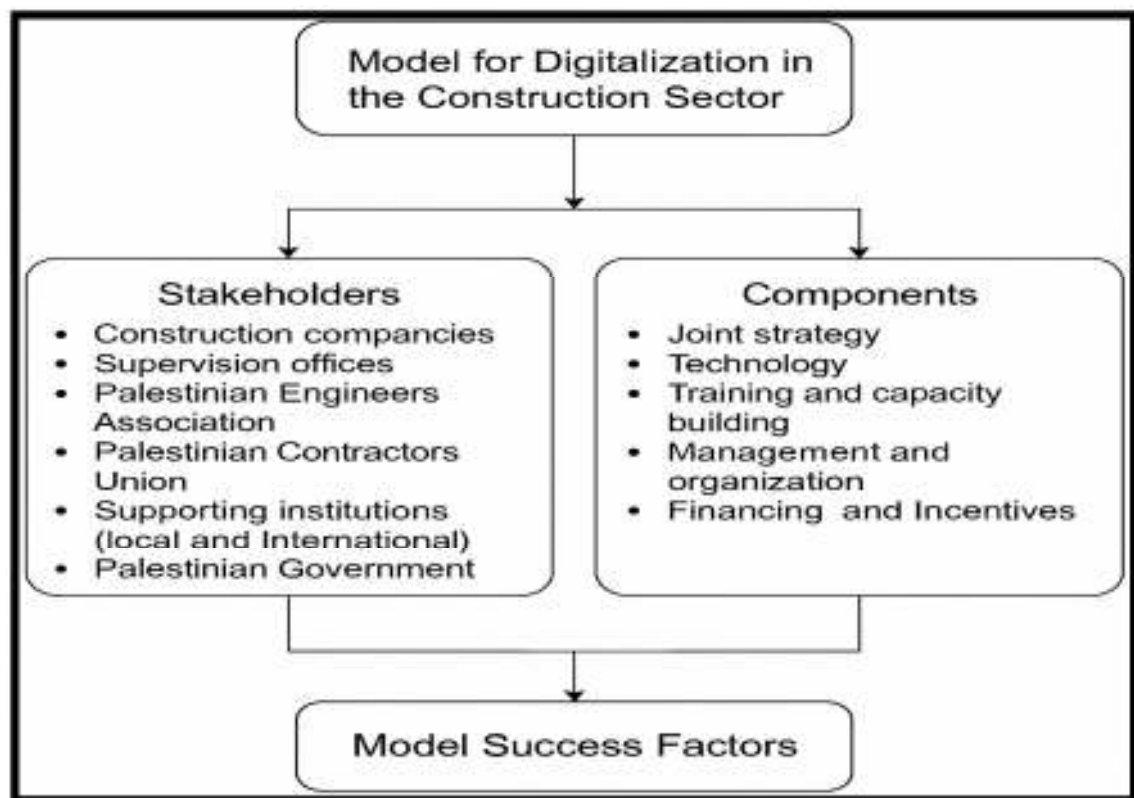
According to (Choi et al., 2021) digital transformation can significantly contributes to improving project efficiency through attaining error-cost reduction in addition to enhancing management transparency (Choi et al., 2021). likewise, decision-making could e enhanced through applying advanced technological tools like; (AI), the internet of things (IoT), clouding storage and (BIM). Accordingly, construction management can efficiently and safely utilize resources establishing ore organized work environment (Bilal et al., 2019).

These technologies help improve productivity and increase investment ta to clarify the appropriate way towards improving the workflow (Bilal et al., 2019). Construction management can implement the (IoT) to manage monitoring the status of equipment and machinery in real time to reduce breakdowns. Whereas cloud computing can provide flexible access to data regardless locations or compounds the matter that really facilitates communication between various parties. BIM is another helpful tool that

enables designing 3D models of projects long before getting into operation or implementation (Dolla et al., 2023). This can consequently create an integrated digital environment that foster the possibility of achieving sustainability and comprehensive development in the field of constructions.in fact, the achievement of digitalization wick enhances both productivity and the construction sector readiness for more completeness, the matter that enables the sector investment for sustainable efficient infrastructure with greater potential returns. See figure (9) below the model the digital transformation in the construction sector in Palestine.

**Figure 9**

*Model for Digitalization in the Construction Sector*



### 5.2.1 Stakeholders and their role in digital transformation

- Construction companies

Construction companies, which initiate a pivotal role in turning to digital transformation, apply advanced technologies like (BIM) to create 3D models to simulate real-world conditions, thereby facilitating more effective planning, design, and implementation (Patil, 2019). Drones also resembling another aspect of digitalization help collect data from work sites, providing accurate information, monitoring project

progress and facilitating decision-making. Moreover, digital project management applications can likely improve coordination between work teams and achieve implementation efficiency (Naji et al., 2024).

- Supervision offices

Supervision offices are responsible for managing quality control and party's compliance with standards and specifications. These offices usually rely on digital analysis systems to monitor work progress and in advance identify potential problems. They also utilize technologies like remote sensing and Internet of Things (IoT) to collect real-time data on environmental conditions and facility safety, ensuring good project performance and avoiding unexpected delays (Egwim et al., 2021).

- Palestinian Engineers Association

The engineer's association has a crucial role in providing engineers with appropriate training and the related digital skills. They develop specific types of digital-training engineering-related curricula regarding the use of engineering software applications and digital process management. The association also regulates professional standards to ensure turning into digital transformation within the best global practices so as to keep engineers ready deal well in a globe's nature of interaction and competition.

- Palestinian Contractors Union

This association is keen to make contractors aware of the necessity of adopting digital transformation, recommending the adoption of digital solutions. The Union encourage contractors to invest in digital tools and machinery through facilitating providing financial supporting in cooperation with financial institutions or parties. In addition, the Union make great efforts to make cooperation with government agencies to enhance implementing digital transformation.

- Supporting institutions (local and international)

Supporting institutions are an essential element in providing the financing and technological expertise necessary for the success of digital transformation. These institutions include government agencies, international donors, and technology companies. These entities support digital infrastructure projects, such as establishing

central data platforms and developing smart applications that help in project management and big data analysis.

- **Palestinian Government**

The Palestinian government has a crucial regulatory and strategic role in the management and organization of digital transformation. They so that through passing legislations and regulating policies that encourage both construction companies and engineering officers opting for digital solutions. Creating reliable excommunication infrastructure including high speed internet and setting up electronic platforms to facilitate linking different entities and exchange data (Zhang et al., 2023). In addition, the government contributes to enhance information security and data protection towards sustainable digital operations.

### **5.2.2 Components of the proposed model**

- **Joint strategy**

Joint-strategy model aims to help cooperating parties or entities contribute state their objectives and achieve either's as well within the macro-joint vision towards adopting digital transformation via setting up a joint-central digital platform. This model allows easy flexible exchange and upgrade level of coordination between the parties involved for further success (Dolla et al., 2023).

- **Technology**

This section refers to adopting the technologies needed and inserting the electronic platforms to make abstract visions true. While technologies involve tools like (AI) for data analysis and decision making, (IoT) for site monitoring and cloud computing for data securing and monitoring (Naji et al., 2024). construction stakeholders needs to utilize E-platforms which can help achieve operational efficiency and fast decion-making through having good data access and updating (Ernstsen et al., 2021).

- **Training and capacity building**

Within a vision of applying digital transformation, regular training programs and workshops are held to help professional from the construction sector manage well with the ever-developing related technologies needed for mastering personnel capacity and

skills. The training mainly address engineers and contractors to help them properly use latest engineering software and data analysis techniques in addition to master managing digital projects (Purwanto et al., 2023).

- Management and organization

Here, construction parties set up a joint-coordinating committee, representing the entities involved, to control over the process of digital transformation. The committee takes responsibility for closely and eventually investigating the strategies applied, measuring or assessing performance, evaluating the extent of the goals achieved and finally having control over system development to endure compliance with digital standardization and quality.

- Financing and Incentives

This model also offers providing construction companies, those opting for digital solutions in particular, with financial incentives and facilities. These procedures would include tax-exemptions and financial support. It also sets up funds to help small and medium-sized contractor invest in digital transformation.

- Laws and Policies

While some polices intent to obligate implementing digital transformation in construction sector, it is thought that new efficient legislations should be passed to help support real application of laws and to regulate implementing digital transformation in the construction sector. This should also include data protection and cyber security enhancement. This might in consequent help accelerate efforts towards attaining turning into digitalization, enhancing an atmosphere of competition on national and international levels.

### **5.2.3 Model Success Factors**

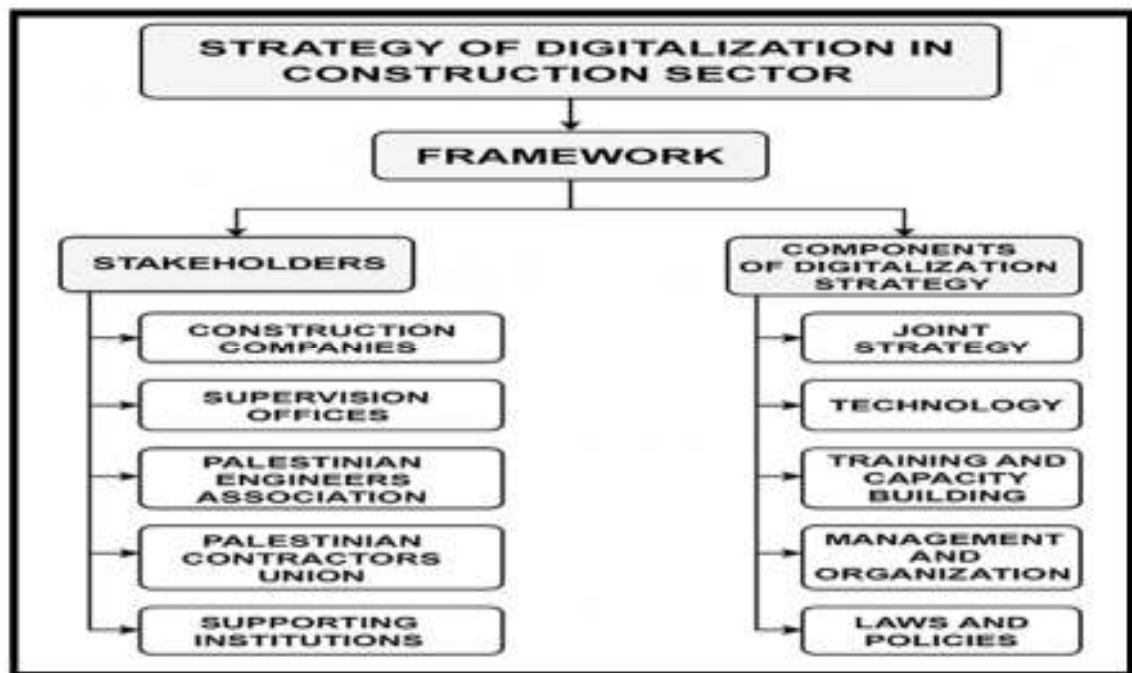
1. Setting up a modern technological infrastructure with high capacity devices, reliable internet network and integrated E-platforms.
2. Promoting electronic culturing through encouraging the spread of innovation and digitalization among engineering and contracting institutions.
3. Providing funds to support companies opting for digital solutions.

4. Qualifying engineering, technical professionals and employees through conducting ongoing training programs to improve their digital skills.

To make real cooperation between construction stakeholders through founding the required technological conditions, this model can actually contribute to have a comprehensive and sustainable digital transformation in the Palestinian sector of constructions. The implementation of this model is expected to improve the quality of service provided, reduce costs, maintain projects sustainability and generally improve the sector's efficiency towards encountering potential challenges. By implementing this model, work quality will be improved, costs will be reduced, and sustainability in construction projects will be increased, which will enhance the efficiency of the sector and support it in facing future challenges. Figure (10) below illustrates the proposed model.

**Figure 10**

*Proposed model for developing digital transformation*



## Chapter Six

### Managerial Implications and Future Studies

This chapter introduces the present study's contributions, challenges, recommendations and potentials for further studies.

#### 6.1 Theoretical implications

From a theoretical perspective, this study makes several contributions to the relatively limited body of research on digital transformation, digital maturity, and construction project performance. Firstly, it addresses a significant gap in the literature by examining how digital transformation strategies—encompassing strategic planning, technological integration, and human resource development—impact organizational project performance, particularly within the Palestinian construction sector. Findings of the present study also indicate that the actual implementation of strategic planning, technological integration, and human resource development probably make significant developments in projects' efficiency, quality and productivity.

Secondly, the present study tests the validity of a theoretical framework that integrates digital transformation, digital maturity, and project performance. This validity can be achieved through implementing (PLS-SEM), a methodology that is rarely utilized in the Palestinian construction sector. The present study, thirdly, offers renewed understandings about the role of digital maturity, as a partial mediator in the association of digital transformation and project performance. Lastly, the study advances theoretical understanding by exploring the interplay between advanced technologies, such as Building Information Modeling (BIM) and the Internet of Things (IoT), and the challenges associated with their adoption in environments constrained by political and economic factors. These insights provide a robust foundation for future research in this field.

#### 6.2 Practical implications

This study has shed light on both the practical and theoretical implications of digital transformation. From a practical perspective, previous studies, like Patil (2019) and Kim et al. (2023), have signified the role of digital transformation in improving the performance of construction companies. Relying on these researchers' insights, the

present study emphasizes the significance of implementing digital transformation strategies: strategic planning, technological integrity, and developing human resources. These factors are really essential for the achievement of project objectives; like time management, cost control, quality assurance, and scope definition. This study also highlights the significance of advancing digital maturity through adopting various technological tools; like (BIM), cloud computing, and (IoT).

Yet, applying digital transformation in Palestine seems limited with a lot of political, economic, and social hindrances. This means increasing awareness and commitment from both policymakers and leaders of various industries. Findings of the present study, nevertheless, have revealed that successful implementation of digital transformation embedded with advanced digital maturity can crucially foster construction project performance. Accordingly, the study findings encourage construction companies to give top priority to investment in a digitalized infrastructure, upgrade their employees' related skills, and adopt a systematic, integrated digital transformation strategy. This can in advance, help the companies identify their needs and get ready for further planning.

In this context, a framework has been developed to help construction managers improve performance by integrating digital transformation into daily operations and strategies. Senior management must commit to supporting digital transformation and developing a sustainable work environment that adapts to technological developments. In addition, the needs and expectations of stakeholders must be integrated into digital transformation processes to ensure that project objectives are achieved comprehensively and sustainably.

### **6.3 Limitations and future research work**

Like other studies, the current research also has several limitations. First, although the sample size (143 companies out of 333) was statistically acceptable, it represents less than half of the total population. This may reduce the generalizability of the results to all construction companies in Palestine. Therefore, future studies are advised to expand the sample size to ensure broader representation. Second, the research was limited to the Palestinian context, which is characterized by unstable political and economic conditions. This may limit the applicability of the findings to other regions. It is

therefore recommended to conduct comparative studies in other developing countries to validate the model in diverse contexts. Third, the study did not explore the role of organizational culture, despite its recognized importance in supporting or hindering digital transformation initiatives. Since cultural change takes time, future research should adopt longitudinal approaches to examine its long-term impact. Finally, the study overlooked financial challenges facing small and medium-sized enterprises (SMEs), which often lack sufficient resources for digital transformation. Future research should focus on SMEs by identifying appropriate support mechanisms, designing tailored maturity models, and assessing how digital maturity influences performance in different organizational settings.

## List of Abbreviations

Abbreviation	Meaning
AI	artificial intelligence
AMC/G	Atomic-Molecular Conditional/Generator
ANN	Neural Network Optimization
ANP	Analytic Network Procedure
AVE	Average Variance Extracted
BIM	Building Information Modeling
CART	Classification and Regression Tree
CB	Construction Businesses
CBR	Case-Based Reasoning
CI	Construction Industry
CI	Computational Intelligence
CM	Construction Management
CP	Construction Projects
CPM	Critical Path Method
CR	Composite Reliability
DT	Decision Tree
EMLA	Ensemble Machine Learning Algorithms
FCIPs	Field Channel Improvement Projects
FL	Fuzzy Logic
GA	Genetic Algorithms
HTMT	Heterotrait–Monotrait Ratio of Correlations
IoT	Internet of Things
ITB	Invitation to Bid
MAPE	Mean Absolute Percentage Error
MAS	Multiple Agents System
MCDM	Multi-Criteria Decision-Making
OSC	Off-Site Construction
PCCTs	Prefabricated Construction Component Technologies
PLS-SEM	Partial Least Squares Structural Equation Modelling
PPI	Protein–Protein Interaction
QS	Quantity Surveying

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RF	Random Forests
RF-GA	Random Forest and Genetic Algorithm
SVM	Support Vector Machines
TOPSIS	Technique for Order Preference by Similarity to the Ideal Solution
VAF	Variance Accounted For
VIF	Variance Inflation Factor

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**Appendices**  
**Appendix A**  
**Questionnaire**

An-Najah National University

Faculty of Graduate Studies / Engineering Management Program



**DIGITAL TRANSFORMATION IN CONSTRUCTION MANAGEMENT:  
ASSESSING THE READINESS OF PALESTINIAN COMPANIES**

Dear Reader:

Greetings

First of all, we thank you for taking the time to complete this questionnaire, and we hope that God will fulfill your hopes and ambitions. I am the student Azmi Qabaja, Master of Engineering Management, An-Najah National University. My goal is to conduct scientific research to complete the requirements of the thesis. This questionnaire was designed to help complete this research and will be used for scientific purposes only.

The questionnaire consists of four main sections:

Section One: General information for the reader

Section Two: Factors affecting the empowerment of digital transformation

Section Three: Maturity of digital transformation as a mediator of the relationship

Section Four: The impact of digital transformation on the performance of construction projects

The expected time to complete the questionnaire is 15 minutes.

Please read all paragraphs of the questionnaire carefully, and put the degree you see fit in front of each paragraph objectively and neutrally. Note that all information will be confidential and will only be used for scientific research purposes.

**Thank you for your cooperation and please accept my highest respect**

**Eng. Azmi Qabaja**



**Section Two: Factors Affecting Enabling Digital Transformation**

	Strongly Agree	Agree	Neutral	Disagree	strongly disagree
<b>Part One: The Impact of Strategy on Companies' Ability to Adopt Digital Transformation</b>					
Our current corporate strategy is aligned with industry trends in digital innovation.					
The company's current digital strategy ensures cybersecurity risk management.					
Digital transformation is an essential part of our long-term corporate strategy.					
We are constantly updating our technology to remain competitive in the digital landscape.					
The current strategy includes adequate training programs to prepare employees for digital transformation.					
The current strategy has increased leadership support for digital transformation initiatives.					
<b>Part Two: The Impact of Technology on Companies' Ability to Embrace Digital Transformation</b>					
Current technology integrates well with existing systems and processes in our construction projects.					
The company's current IT systems support digital collaboration across departments.					
Using current technology has streamlined project workflows and increased efficiency.					
Adopting current technology has significantly reduced time spent on manual tasks.					
Current technology has contributed to better planning and forecasting of construction projects.					
Current technology has made it easier to overcome the challenges associated with adopting new digital tools.					
<b>Part Three, The Impact of HR on Companies' Ability to Adopt Digital Transformation</b>					
HR effectively recruits employees with the skills needed to digitally transform construction projects.					
HR provides comprehensive training programs to prepare employees for digital transformation.					

	Strongly Agree	Agree	Neutral	Disagree	strongly disagree
HR provides adequate support to employees who face challenges in adapting to digital tools.					
HR fosters a culture that supports innovation and digital transformation.					
HR includes digital transformation achievements in performance evaluations.					
HR initiatives have positively impacted employee engagement and motivation towards adopting digital technologies.					
<b>Section 3: Enabling digital transformation maturity as a mediator in the relationship between digital transformation adoption and construction project management performance.</b>					
Awareness of the importance of digital transformation in the company is beginning to emerge, but without an integrated strategic vision.					
Digital technologies are being adopted in the company's projects, such as Building Information Modeling (BIM), Big Data Management.					
Digital solutions are being integrated into all project phases (design, planning, implementation, and operation), with extensive use of technologies such as Artificial Intelligence, Internet of Things (IoT), and Big Data Analysis.					
The company is able to quickly adapt to changes in the technological environment and achieve continuous innovation.					
The digital strategy is regularly reviewed and updated to ensure adaptation to new technologies.					
Cybersecurity systems are regularly updated to address potential digital threats.					
<b>Section Four: The Impact of Digital Transformation on Construction Project Performance</b>					
<b>Part One: The Impact of Digital Transformation on Construction Project Time Performance</b>					
In your opinion, will digital transformation help significantly reduce the time required to complete project tasks					
In your opinion, the use of digital tools improves the timeliness of meeting project deadlines.					

	<b>Strongly Agree</b>	<b>Agree</b>	<b>Neutral</b>	<b>Disagree</b>	<b>strongly disagree</b>
In your opinion, digital transformation helps adjust the due dates of achievements associated with work packages.					
In your opinion, digital project management tools simplify the scheduling process.					
In your opinion, does digital -technology improve faster decision ?making					
<b>Part Two: The Impact of Digital Transformation on Construction Project Cost Performance</b>					
In your opinion, the use of digital costs of tools reduces the overall .the project					
In your opinion, digital transformation helps risk management document the funding needed to perform various risk management activities.					
In your opinion, digital technologies help control variable costs for cost overruns in projects.					
In your opinion, digital budgeting tools improve the accuracy of cost forecasting.					
In your opinion, the implementation of digital processes helps reduce labor costs through automation.					
<b>Part Three: The Impact of Digital Transformation on Quality Performance Construction Projects</b>					
In your opinion, will digital technology help improve the overall quality of construction project results?					
In your opinion, digital tools help improve compliance with quality standards in construction projects.					
In your opinion, the use of digital tools enhances the quality control process on site.					
In your opinion, digital technology helps identify sources of quality risks such as poor implementation or the use of untested technologies.					
In your opinion, digital transformation helps reduce defects and rework in construction projects.					
<b>Part Four: The Impact of Digital Transformation on the Scope of Construction Projects</b>					
In your opinion, digital technology supports effective management of project scope expansion.					

	<b>Strongly Agree</b>	<b>Agree</b>	<b>Neutral</b>	<b>Disagree</b>	<b>strongly disagree</b>
In your opinion, the use of digital tools enhances the alignment of the project scope with the client's requirements.					
In your opinion, digital transformation helps in developing a scope management plan that is compatible and consistent with the development approach, life cycle description, change management plan, requirements management plan and release and iteration plan.					
In your opinion, digital technology helps in integrating information about how business analysis activities and project management activities interact.					
In your opinion, digital technology helps in integrating scope and requirements, describing how project and product requirements are addressed in the scope statement and work breakdown structure.					

Are there any other comments or suggestions you would like to add?

.....

.....

## Appendix B

### Questionnaire



جامعة النجاح الوطنية

كلية الدراسات العليا / ماجستير إدارة هندسية

التحول الرقمي في إدارة الإنشاءات: تقييم جاهزية الشركات الفلسطينية

عزيزي القارئ/ عزيزتي القارئة،

تحية طيبة،

في البداية نشكركم لتخصيص جزء من وقتكم لإتمام هذا الاستبيان ونرجو من الله أن يحقق آمالكم وطموحاتكم. أنا الطالب عزمي قباجة ماجستير إدارة هندسية من جامعة النجاح الوطنية هدفي القيام ببحث علمي لاستكمال متطلبات الأطروحة وصمم هذا الاستبيان للمساعدة لإتمام هذا البحث وسوف يستخدم للغرض العلمي فقط.

يتكون الاستبيان من أربعة أقسام رئيسية،

القسم الأول: معلومات عامة تخص القارئ/القارئة

القسم الثاني: العوامل المؤثرة على تمكين التحول الرقمي

القسم الثالث: نضج التحول الرقمي كوسيط للعلاقة

القسم الرابع: تأثير التحول الرقمي على أداء المشاريع الإنشائية

الزمن المتوقع لإتمام الاستبيان هو 15 دقيقة.

الرجاء التفضل بقراءة جميع فقرات الاستبيان بدقة، ووضع الدرجة التي تراها مناسبة امام كل فقرة بموضوعية وحيادية. علما بان كافة المعلومات سوف تكون سرية ولن تستخدم الا لأغراض البحث العلمي.

أشكركم على تعاونكم وتفضلوا بقبول فائق الاحترام

م. عزمي قباجة

القسم الأول: معلومات عامة عن الشركة

الجنس

( ) ذكر ( ) أنثى

يصنف المصنع حسب نوع الشركات

( ) شركة عائلية ( ) مساهمة عامة

( ) مساهمة خاصة ( ) غير ذلك

عدد العاملين في الشركة

( ) 9-5 ( ) 14- 10 ( ) 19-15

( ) 24-20 ( ) 25 فما فوق

تصنيف الشركة لدى اتحاد المقاولين:

( ) تصنيف أول ( ) تصنيف ثاني ( ) تصنيف ثالث

( ) تصنيف رابع ( ) ير ذلك

الموقع الوظيفي

( ) المدير العام /المدير التنفيذي ( ) مدير مشروع ( ) مهندس موقع

( ) المدير الإداري ( ) غير ذلك

الدرجة العلمية

( ) دبلوم ( ) بكالوريوس

( ) ماجستير ( ) دكتوراه

القسم الثاني: العوامل المؤثرة على تمكين التحول الرقمي

الرقم	الفقرة	أوافق بشدة	أوافق	لا اعلم	اعارض بشدة	اعارض
<b>الجزء الأول: تأثير الإستراتيجية على قدرة الشركات في تبني التحول الرقمي</b>						
1.	تتوافق استراتيجية شركتنا الحالية مع اتجاهات الصناعة في مجال الابتكار الرقمي.					
2.	تضمن الاستراتيجية الرقمية الحالية للشركة إدارة مخاطر الأمن السيبراني. تضمن الاستراتيجية الرقمية الحالية للشركة إدارة مخاطر الأمن السيبراني.					
3.	يعد التحول الرقمي جزءاً أساسياً من استراتيجية شركتنا طويلة الأجل.					
4.	نقوم بتحديث تقنيتنا باستمرار لنظل قادرين على المنافسة في المشهد الرقمي.					
5.	تتضمن الاستراتيجية الحالية برامج تدريبية كافية لإعداد الموظفين للتحول الرقمي.					
6.	لقد زادت الاستراتيجية الحالية من دعم القيادة لمبادرات التحول الرقمي.					
<b>الجزء الثاني: تأثير التكنولوجيا على قدرة الشركات في تبني التحول الرقمي</b>						
7.	تتكامل التكنولوجيا الحالية بشكل جيد مع الأنظمة والعمليات الحالية في مشاريع البناء الخاصة بنا.					
8.	تدعم أنظمة تكنولوجيا المعلومات الحالية للشركة التعاون الرقمي عبر الأقسام.					
9.	لقد أدى استخدام التكنولوجيا الحالية إلى تبسيط سير عمل المشروع وزيادة الكفاءة.					
10.	لقد أدى تبني التكنولوجيا الحالية إلى انخفاض ملحوظ في الوقت الذي يقضيه في المهام اليدوية.					
11.	لقد ساهمت التكنولوجيا الحالية في التخطيط والتنبؤ بشكل أفضل لمشاريع البناء.					
12.	لقد سهلت التكنولوجيا الحالية التغلب على التحديات المرتبطة بتبني أدوات رقمية جديدة.					
<b>الجزء الثالث: تأثير الموارد البشرية على قدرة الشركات في تبني التحول الرقمي</b>						
13.	يقوم قسم الموارد البشرية بتوظيف الموظفين ذوي المهارات اللازمة للتحول الرقمي في مشاريع البناء بشكل فعال.					

الرقم	الفقرة	أوافق بشدة	أوافق	لا اعلم	اعارض بشدة	اعارض
14.	يوفر قسم الموارد البشرية برامج تدريبية شاملة لإعداد الموظفين للتحول الرقمي.					
15.	يوفر قسم الموارد البشرية الدعم الكافي للموظفين الذين يواجهون تحديات في التكيف مع الأدوات الرقمية.					
16.	تعزز الموارد البشرية ثقافة تدعم الابتكار والتحول الرقمي.					
17.	تتضمن الموارد البشرية إنجازات التحول الرقمي في تقييمات الأداء.					
18.	لقد أثرت مبادرات الموارد البشرية بشكل إيجابي على مشاركة الموظفين وتحفيزهم نحو تبني التقنيات الرقمية.					
<b>القسم الثالث: تمكين نضج التحول الرقمي كوسيط في العلاقة بين اعتماد التحول الرقمي وأداء إدارة مشاريع البناء.</b>						
19.	الوعي بأهمية التحول الرقمي في الشركة بدأ في الظهور ولكن بدون رؤية استراتيجية متكاملة.					
20.	يتم تبني التقنيات الرقمية في المشاريع الخاصة بالشركة مثل نمذجة معلومات البناء (BIM) ، إدارة البيانات الضخمة.					
21.	يتم دمج الحلول الرقمية في جميع مراحل المشروع (التصميم، التخطيط، التنفيذ، والتشغيل) ، مع استخدام واسع لتقنيات مثل الذكاء الاصطناعي، إنترنت الأشياء (IoT) ، وتحليل البيانات الضخمة.					
22.	الشركة قادرة على التكيف بسرعة مع التغيرات في البيئة التكنولوجية وتحقيق الابتكار المستمر.					
23.	يتم مراجعة وتحديث الاستراتيجيات الرقمية بانتظام لضمان التكيف مع التقنيات الجديدة.					
24.	يتم تحديث أنظمة الأمن السيبراني بانتظام لمواجهة التهديدات الرقمية المحتملة.					
<b>القسم الرابع: تأثير التحول الرقمي على أداء المشاريع الإنشائية</b>						
25.	برأيك هل سوف يساعد التحول الرقمي في تقليل الوقت المطلوب لإكمال مهام المشروع بشكل كبير.					

الرقم	الفقرة	أوافق بشدة	أوافق	لا اعلم	اعارض بشدة	اعارض
26.	برأيك يؤدي استخدام الأدوات الرقمية إلى تحسين القدرة الزمنية على تلبية المواعيد النهائية للمشروع.					
27.	برأيك يساعد التحول الرقمي بضبط تواريخ استحقاق الإنجازات المرتبطة بحزم العمل.					
28.	برأيك تعمل أدوات إدارة المشاريع الرقمية على تبسيط عملية الجدولة.					
29.	برأيك هل تحسن التكنولوجيا الرقمية اتخاذ قرارات أسرع.					
<b>الجزء الأول: تأثير التحول الرقمي على أداء وقت المشاريع الإنشائية</b>						
<b>الجزء الثاني: تأثير التحول الرقمي على أداء التكلفة المشاريع الإنشائية</b>						
30.	برأيك يؤدي استخدام الأدوات الرقمية إلى تقليل التكاليف الإجمالية للمشروع.					
31.	برأيك يساعد التحول الرقمي إدارة المخاطر على توثيق التمويل اللازم لأداء أنشطة إدارة المخاطر المختلفة					
32.	برأيك تساعد التقنيات الرقمية في ضبط الأمور التخيرية ل تجاوز التكاليف في المشاريع.					
33.	برأيك تحسن أدوات الميزانية الرقمية دقة التنبؤ بالتكاليف.					
34.	برأيك تساعد تنفيذ العمليات الرقمية إلى تقليل تكاليف العمالة من خلال الأتمتة.					
<b>الجزء الثالث: تأثير التحول الرقمي على أداء الجودة المشاريع الإنشائية</b>						
35.	برأيك هل ستساعد التكنولوجيا الرقمية إلى تحسين الجودة الشاملة لنتائج مشاريع البناء.					
36.	برأيك تساعد الأدوات الرقمية إلى تحسين الامتثال لمعايير الجودة في مشاريع البناء.					
37.	برأيك يؤدي استخدام الأدوات الرقمية إلى تعزيز عملية مراقبة الجودة في الموقع.					
38.	برأيك تساعد التكنولوجيا الرقمية في تحديد مصادر المخاطر المتعلقة بالجودة مثل: سوء التنفيذ أو استخدام تقنيات غير مجربة.					

الرقم	الفقرة	أوافق بشدة	أوافق	لا اعلم	اعارض بشدة	اعارض
39.	برأيك يساعد التحول الرقمي إلى تقليل العيوب وإعادة العمل في مشاريع البناء.					
40.	الجزء الرابع: تأثير التحول الرقمي على نطاق المشاريع الإنسانية					
41.	برأيك تدعم التكنولوجيا الرقمية الإدارة الفعالة لتوسع نطاق المشروع.					
42.	برأيك يؤدي استخدام الأدوات الرقمية إلى تعزيز توافق نطاق المشروع مع متطلبات العميل.					
43.	برأيك يساعد التحول الرقمي في وضع خطة إدارة النطاق متوافقة ومتسقة مع نهج التطوير، وصف دورة الحياة، خطة إدارة التغيير، خطة إدارة المتطلبات و خطة الإصدار والتكرار					
44.	برأيك تساعد التكنولوجيا الرقمية في دمج المعلومات حول كيفية تفاعل أنشطة تحليل الأعمال وأنشطة إدارة المشروع.					
45.	برأيك تساعد التكنولوجيا الرقمية تكامل النطاق والمتطلبات وصف كيفية معالجة متطلبات المشروع والمنتج في بيان النطاق وهيكل تقسيم العمل.					

هل يوجد أي ملاحظات او اقتراحات أخرى تودون اضافتها ؟

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## Appendix C

### Multivariate Analysis (MANOVA)

Source	Dependent variables		Tests of Between-Subjects Effects					Variance Resource	
								Wilks' Lambda	
			Type III Sum of Squares	df	Mean Square	F	Sig.	Value	Sig.
Gender	Adoption of digital transformation	Str	1.638	1	1.638	5.267	0.026	0.290	0.042
		Tch	0.887	1	0.887	4.538	0.038		
		Hr	1.767	1	1.767	6.242	0.016		
		Total degree	1.401	1	1.401	5.689	0.021		
	Digitalization Maturity (DM)		3.371	1	3.371	9.444	0.003		
	Management Performance	Tim	0.819	1	0.819	4.925	0.031		
		Cst	1.193	1	1.193	7.791	0.007		
		Qty	1.224	1	1.224	6.432	0.014		
		Rng	1.212	1	1.212	7.502	0.008		
		Total degree	1.105	1	1.105	7.137	0.010		
Company classification by company type	Adoption of digital transformation	Str	2.622	3	0.874	2.810	0.049	1.855	0.000
		Tch	0.980	3	0.327	1.671	0.185		
		Hr	1.244	3	0.415	1.464	0.235		
		Total degree	1.056	3	0.352	1.430	0.245		
	Digitalization Maturity (DM)		1.226	3	0.409	1.145	0.340		
	Management Performance	Tim	1.343	3	0.448	2.691	0.056		
		Cst	2.995	3	0.998	6.520	0.001		
		Qty	0.959	3	0.320	1.679	0.183		
		Rng	0.410	3	0.137	0.846	0.475		
		Total degree	1.047	3	0.349	2.255	0.093		
Number of employees in the company	Adoption of digital transformation	Str	4.637	4	1.159	3.727	0.010	1.979	0.000
		Tch	2.859	4	0.715	3.656	0.011		
		Hr	3.623	4	0.906	3.199	0.020		
		Total degree	3.309	4	0.827	3.359	0.016		
	Digitalization Maturity (DM)		0.453	4	0.113	0.318	0.865		
	Management Performance	Tim	1.532	4	0.383	2.302	0.071		
		Cst	1.862	4	0.466	3.040	0.025		
		Qty	0.419	4	0.105	0.550	0.700		
		Rng	1.081	4	0.270	1.673	0.171		

Source	Dependent variables		Tests of Between-Subjects Effects					Variance Resource	
								Wilks' Lambda	
			Type III Sum of Squares	df	Mean Square	F	Sig.	Value	Sig.
		Total degree	0.921	4	0.230	1.487	0.220		
Company classification with the Contractors Union	Adoption of digital transformation	Str	4.857	4	1.214	3.904	0.008	1.408	0.000
		Tch	1.827	4	0.457	2.337	0.068		
		Hr	3.422	4	0.855	3.022	0.026		
		Total degree	3.040	4	0.760	3.086	0.024		
	Digitalization Maturity (DM)		0.737	4	0.184	0.516	0.724		
	Management Performance	Tim	1.332	4	0.333	2.002	0.108		
		Cst	0.331	4	0.083	0.541	0.706		
		Qty	0.283	4	0.071	0.372	0.827		
		Rng	0.111	4	0.028	0.172	0.951		
		Total degree	0.207	4	0.052	0.334	0.854		
Job	Adoption of digital transformation	Str	2.227	3	0.742	2.387	0.080	0.927	0.000
		Tch	1.118	3	0.373	1.907	0.140		
		Hr	3.031	3	1.010	3.569	0.020		
		Total degree	1.920	3	0.640	2.598	0.062		
	Digitalization Maturity (DM)		2.693	3	0.898	2.515	0.069		
	Management Performance	Tim	1.709	3	0.570	3.424	0.024		
		Cst	2.013	3	0.671	4.381	0.008		
		Qty	1.825	3	0.608	3.197	0.031		
		Rng	2.160	3	0.720	4.459	0.007		
		Total degree	1.895	3	0.632	4.081	0.011		
Educational degree	Adoption of digital transformation	Str	1.760	3	0.587	1.887	0.144	1.093	0.000
		Tch	0.361	3	0.120	0.615	0.608		
		Hr	1.360	3	0.453	1.601	0.201		
		Total degree	1.024	3	0.341	1.386	0.258		
	Digitalization Maturity (DM)		1.717	3	0.572	1.604	0.200		
	Management Performance	Tim	0.947	3	0.316	1.897	0.142		
		Cst	0.719	3	0.240	1.566	0.209		
		Qty	0.921	3	0.307	1.613	0.198		
		Rng	1.913	3	0.638	3.948	0.013		
		Total degree	0.778	3	0.259	1.676	0.184		

Source	Dependent variables		Tests of Between-Subjects Effects					Variance Resource	
								Wilks' Lambda	
			Type III Sum of Squares	df	Mean Square	F	Sig.	Value	Sig.
Error	Adoption of digital transformation	Str	15.863	51	0.311				
		Tch	9.971	51	0.196				
		Hr	14.439	51	0.283				
		Total degree	12.561	51	0.246				
	Digitalization Maturity (DM)		18.204	51	0.357				
	Management Performance	Tim	8.483	51	0.166				
		Cst	7.810	51	0.153				
		Qty	9.703	51	0.190				
		Rng	8.237	51	0.162				
		Total degree	7.895	51	0.155				
Total	Adoption of digital transformation	Str	2025.222	143					
		Tch	2326.806	143					
		Hr	2003.778	143					
		Total degree	2101.725	143					
	Digitalization Maturity (DM)		2005.306	143					
	Management Performance	Tim	2577.960	143					
		Cst	2480.240	143					
		Qty	2590.120	143					
		Rng	2575.480	143					
		Total degree	2546.233	143					
Corrected Total	Adoption of digital transformation	Str	151.245	142					
		Tch	82.594	142					
		Hr	129.800	142					
		Total degree	108.042	142					
	Digitalization Maturity (DM)		115.608	142					
	Management Performance	Tim	68.862	142					
		Cst	69.024	142					
		Qty	57.510	142					
		Rng	56.319	142					
		Total degree	53.444	142					

## Appendix D

### Model Fit

	<b>Saturated model</b>	<b>Estimated model</b>
SRMR	0.049	0.049
d_ULS	0.161	0.161
d_G	0.177	0.177
Chi-square	144.160	144.160
NFI	0.910	0.910

## Appendix E

### Results of R<sup>2</sup>, f<sup>2</sup> and Q<sup>2</sup> value

<b>Construct</b>	<b>R<sup>2</sup> adj</b>	<b>Q<sup>2</sup></b>	<b>f<sup>2</sup> MP</b>
ADT	-	-	0.079 (small)
MP	0.695 (high)	0.349	-
DM	0.383 (high)	0.682	0.030 (small)

## Appendix F

### Hypothesis testing results

<b>Path</b>	<b>Hypothesis</b>	<b><math>\beta</math>-value</b>	<b>Std. Error</b>	<b>T-value</b>	<b>P-value</b>	<b>Decision</b>
ADT→MP	H1	0.399	0.125	3.182	0.001	Supported
ADT→DM	H2	0.834	0.026	32.341	0.000	Supported
DM→MP	H3	0.399	0.125	3.182	0.001	Supported
ADT→MP	Total Effect	0.604	0.055	10.911	0.000	Supported
ADT→DM→MP (indirect)	H4	0.205	0.097	2.110	0.035	



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تقييم جاهزية الشركات الفلسطينية

إعداد

عزمي ماجد عزمي قباجة

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قدمت هذه الرسالة استكمالاً لمتطلبات الحصول على درجة الماجستير في الإدارة الهندسية،  
من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس - فلسطين.

## التحول الرقمي في إدارة الإنشاءات: تقييم جاهزية الشركات الفلسطينية

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### الملخص

تبحث هذه الدراسة في مدى جاهزية شركات الإنشاءات الفلسطينية لتبني التحول الرقمي باستخدام أدوات الذكاء الاصطناعي، مع تحديد التحديات المرتبطة به واقتراح حلول استراتيجية. في ضوء انخفاض الإنتاجية وهوامش الربح الهامشية في قطاع الإنشاءات، يُنظر إلى التحول الرقمي كمحرك لتحسين أداء المشاريع والابتكار. تُقيم الدراسة كيف تؤثر الاستراتيجية والبنية التحتية التكنولوجية والموارد البشرية على تبني التحول الرقمي، وتدرس النضج الرقمي كعامل وسيط. تم اعتماد نهج مختلط الأساليب. تم جمع البيانات النوعية من خلال 13 مقابلة شبه منظمة، بينما تم الحصول على البيانات الكمية من خلال استبيان منظم تم توزيعه على 333 شركة، مع 143 استجابة صحيحة (معدل الاستجابة: 42.9%). تم استخدام تقنية نمذجة المعادلات الهيكلية للمربعات الصغرى الجزئية (PLS-SEM) لتحليل البيانات. تكشف النتائج أن مستوى تبني التحول الرقمي (ADT) كان مرتفعاً (المتوسط = 5/3.73)، وسجل النضج الرقمي (DM) متوسطاً قدره 3.64، بينما أظهر أداء المشروع (MP) مستوى مرتفعاً جداً (المتوسط = 4.18). ومن بين أبعاد ADT، كان للتكنولوجيا أعلى تأثير (المتوسط = 3.96)، تليها الاستراتيجية والموارد البشرية (المتوسط = 3.62 لكل منهما). وأظهر النموذج الهيكلي علاقات قوية وهامة بين تبني التحول الرقمي وأداء المشروع ( $R^2 = 0.712$ )، حيث يتوسط النضج الرقمي هذه العلاقة جزئياً ( $VAF = 52\%$ ). وتشمل التحديات الرئيسية التي تم تحديدها ضعف المهارات الرقمية والبنية التحتية المحدودة والقيود التنظيمية. واستجابة لذلك، تقترح الدراسة إطاراً استراتيجياً يتضمن: (1) الاستثمار في البنية التحتية الرقمية الحديثة، (2) تطوير الكفاءات الرقمية،

و(3) الإصلاح التنظيمي. وتهدف هذه الاستراتيجيات إلى تعزيز التبني الرقمي وضمان تحقيق مكاسب أداء مستدامة في قطاع البناء الفلسطيني. يقدم هذا البحث أدلة تجريبية على جاهزية التحول الرقمي ويساهم في تقديم حلول عملية وتوصيات سياسية لتسريع التحول الرقمي في أسواق البناء النامية.

**الكلمات المفتاحية:** التحول الرقمي، الذكاء الاصطناعي، إدارة الإنشاءات، النضج الرقمي، شركات الإنشاءات الفلسطينية، أداء المشروع، الإطار الاستراتيجي، البنية التحتية التكنولوجية، الموارد البشرية، نمذجة معلومات البناء، إنترنت الأشياء