

Designer Knowledge's Effect On Construction Project's Performance In Saudi Arabia

BY

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A Thesis Presented to the
COLLEGE OF GRADUATE AND INTERDISCIPLINARY STUDIES
KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

Construction Engineering and Management

December 2023

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
DHAHRAN- 31261, SAUDI ARABIA
DEANSHIP OF GRADUATE STUDIES

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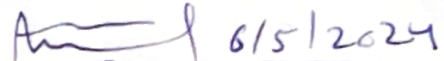
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I am dedicating this research thesis to my role model father Professor
Mohamed Abouelresh, mom, sisters, friends and to my CEM department at
KFUPM

ACKNOWLEDGMENTS

I am pledging my thesis to several individuals who have played crucial roles in my academic journey. Firstly, I would like to express my heartfelt gratitude to Professor Ali Shash, my advisor, for his unwavering help, guidance, and support throughout the research process. I also want to thank my loved ones, my close friends, and my family for their encouragement and understanding during my studies.

In addition, I am grateful to my committee advisors, Dr. Awsan Mohammed and Dr. Khwaja Nasser, for their valuable insights and advice that have significantly contributed to the success of my thesis. Lastly, I would like to thank my employer, Tabby, and specifically my direct line manager, Mr. Abdulaziz Saja, for his continued support during my studies. He has been incredibly understanding and supportive towards my MSc journey, and I appreciate his constant encouragement and assistance.

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LIST OF ABBREVIATIONS

SCE	:	Saudi Concuil of Engineers
DK	:	Designer Knowledge
KP	:	Knowledge Process (KP)
KT	:	Knowledge Technology (KT)
KC	:	Knowledge culture (KC)
KL	:	Knowledge leadership (KL)
KA	:	Knowledge Acquisition (KA)
KS	:	Knowledge Sharing (KS)
KR	:	Knowledge Retention (KR)
KE	:	Knowledge Education (KE)
KQ	:	Knowledge Quality (KQ)
KC	:	Knowledge Financing (KC)
KR	:	Knowledge Retention (KR)
KE	:	Knowledge Education (KE)
KQ	:	Knowledge Quality (KQ)
KC	:	Knowledge Financing (KC)
PPPO	:	Project Performance Project Objectives
PPTS	:	Project Performance Team Satisfaction
PPCS	:	Project Performance Costumer Service

ABSTRACT

Full Name : Ahmed Mohamed Ibrahim
Thesis Title : Designer Knowledge's Effect on Construction Project's Performance in Saudi Arabia
Major Field : Construction Engineering & Management
Date of Degree : December 2023

This thesis investigates the intricate relationship between knowledge management and project performance in the domain of construction design, with a specific focus on designers in Saudi Arabia. Recognizing the pivotal role of designers in shaping construction projects, the research explores the impact of their construction knowledge on project outcomes. The study employs a quantitative approach, conducting a survey among professionals in grade 1 and grade 2 design offices that were classified as excellent by Saudi Council of Engineers (SEC) in the Eastern Province of Saudi Arabia. The technique used for analyzing the data was the partial least squares structural equation modeling (PLS-SEM). Key findings from the analysis highlights Knowledge Leadership and Knowledge Technology as central dimensions with the highest impact on project performance.

The research contends that designers with extensive knowledge are more likely to create designs aligned with project objectives, financial constraints, and temporal limitations. In contrast, insufficient knowledge may lead to unfavorable design choices and substantial project challenges. The study addresses a critical gap in existing literature, particularly in the context of the Saudi Arabian construction industry amid the transformative Vision 2030. Recommendations are tailored for designers, organizational leaders, educators, and industry stakeholders to enhance project performance through effective knowledge management.

The research emphasizes strategic prioritization of knowledge management factors and provides actionable insights for decision-makers in construction project management.

The study's significance lies in contributing to the understanding of the correlation between designer's construction knowledge and project performance, offering a roadmap for improving construction projects in alignment with Vision 2030. Future research avenues are suggested to deepen the understanding of specific knowledge factors and explore the long-term impact of knowledge management practices in the dynamic construction industry.

]

CHAPTER 1

[INTRODUCTION]

1.1 [Background of Study

Various factors impact project performance (design package) in the domain of construction design, one of which is the designer's knowledge. Constructing a building encompasses multiple stages, from the initial conceptualization to the final implementation. Each phase necessitates the involvement of various experts, such as architects, engineers, and contractors. The phase of construction design assesses a project's viability by examining its structural soundness, practicality, and visual appeal. A comprehensive understanding of construction design principles is imperative for attaining a favorable outcome in a project. The previous knowledge encompasses comprehension of construction materials, structural frameworks, building ordinances and standards, ecological aspects, and energy conservation. Designers possessing extensive knowledge are more inclined to create designs that fulfill project objectives and requirements, comply with financial and temporal limitations, and provide viable and long-lasting resolutions. On the contrary, insufficient knowledge may result in unfavorable design choices and substantial project challenges, including schedule extensions, financial excesses, and substandard deliverables.

Currently, minimal research addresses the impact of designer construction knowledge on the construction industry in general and in Saudi Arabia in particular. This research provides background information on the different types of knowledge management factors, A Brief History of Construction, Designer Construction Knowledge, Designer Knowledge: Roles and Responsibilities, Introduction into Project Performance. Project Performance Factors, Designer Knowledge effect on Project Performance, Constructability, and Constructability Implementation. The background information provided demonstrates how changes in the industry have affected the ability of designers to obtain appropriate construction knowledge.

This thesis presents background information on knowledge management, the research scope, methodology, objective and purpose, constructability reviews, and construction management methods. It presents how the research was conducted, project participants, how the data was analyzed, and how the results can be used by personnel in the construction industry to establish guidelines to improve designer construction knowledge and modify current knowledge management approach.

1.2 Statement of the Problem

This study's main claim is that, in the context of Saudi Arabia, the designers' construction knowledge significantly impacts the success of construction projects through sound the preparation of sound project documents. The construction industry has long been associated with poor project performances worldwide, characterized by delays, cost overruns, construction waste, low productivity, and compromised quality. Many researchers have consistently linked these issues to ineffective resource management in construction projects (Shehata and El-Gohary, 2011; Meng, 2012). Findings from studies conducted on numerous construction projects in different countries, including the UK, Europe, and beyond, confirm the rarity of projects being completed on schedule (Morris and Hough, 1998; Al-Hammad, 1993; Arditi et al., 1985; Assaf et al., 1995; Rad, 1979; Taha et al., 1993). Furthermore, the significance of poor design packages as a contributing factor to delays, cost overrun, and low productivity has been widely documented in the existing literature.

Building upon this body of knowledge, it is essential to examine the current state of architectural construction knowledge and its implications. By exploring the impact of design packages on project performance and the effectiveness of resource management, we can identify areas for improvement and devise strategies to enhance project outcomes. Understanding the underlying challenges and opportunities in this field will enable us to drive positive change and promote greater efficiency, cost-effectiveness, and quality within architectural construction projects.

The central argument put forth in this thesis posits that there exists a noteworthy correlation between the construction knowledge and the overall performance of construction projects. The thesis further posits that designers can exert a considerable impact in this regard, given their pivotal role in the success of construction projects. Specifically, designers are responsible for creating designs, plans, and specifications for buildings to ensure that they align with the clients' needs and requirements. The thesis posits that in order to achieve superior outcomes, it is imperative that the proficiency and aptitude of designers be aligned with the demands of the project and the expectations of the stakeholders.

Furthermore, the thesis underscores the significance of cooperative endeavors among designers, stakeholders, and project managers in attaining the most favorable project outcomes. The thesis statement functions as a navigational tool for the research undertaken in this study, furnishing a distinct concentration and orientation to the inquiry.

The construction industry has different types of problems and most of them are related to the design process and the management of projects. Excessive amounts of manpower and money have been invested in determining solutions to the problems that arise during construction processes. Constructability, different types of project delivery systems, and construction management are areas that have received the most attention in recent years. Incorporation of constructability reviews into the early design stage of projects may produce better project results. The results of several research investigations indicated that contractors and construction managers should provide constructability information during project design.

Moreover, the designer's construction knowledge is of utmost importance in guaranteeing the triumphant execution of a construction undertaking. Insufficient construction knowledge in design is expected to impede the capacity to proficiently, efficaciously, and expediently accomplish tasks. In order to effectively carry out their duties related to task delivery, design interpretation, construction interfaces, and coordination, the designer must possess a comprehensive understanding of various aspects of construction.

The construction knowledge of a designer encompasses not only technical proficiency but also proficiencies in communication, collaboration, and stakeholder management. Proficiency in designer software facilitates efficient analysis, communication, and dissemination of design files among other professionals involved in the construction process. In summary, possessing designer construction knowledge is crucial in attaining triumph in construction projects, while its absence may result in project setbacks, escalated construction expenses, and diminished project excellence.

Research Questions

1. What is the construction knowledge that a designer shall acquires to produce quality designs package? (Construction Knowledge Dimensions)
2. What is the level of construction knowledge a designer in Saudi Arabia has?
3. What are the sources for improving a designer construction knowledge?
4. How to improve a designer construction knowledge?
5. How does a designer's construction knowledge affect the project document (design package)?

The correlation between the construction knowledge of designers and the outcome of projects holds immense importance and should not be underestimated. Employing a construction designer with comprehensive expertise and experience can yield significant advantages for a project team. Initially, the caliber of the project will probably improve. A designer with great construction knowledge can recognize potential challenges and provide suggestions for remediation that may have gone undetected. Furthermore, the project can be executed with greater efficiency, resulting in a reduction in the duration of completion and a mitigation of potential delays.

Ultimately, designers possessing extensive construction knowledge are more adept at managing expenses and quality. They can offer guidance regarding cost-effective solutions and can assist in preventing the occurrence of expensive unforeseen alterations in the future. In summary, the correlation between the expertise of construction designers and the performance of a project significantly influences crucial aspects such as quality, time, and cost, which are determinants of the project's ultimate success.

1.3 Objective of Study

The objective of this research is to develop a framework to measure the level of construction knowledge of Designers in Saudi Arabia. Moreover, the study aims to assess whether the knowledge level affects the projects performance (design package), as well as the effect of this level of construction knowledge could affect the project performance.

The objective of this research is to measure the effect of the designer knowledge on the project performance. The main objectives of the presented research are the following:

- To fully and practically evaluate the level of construction Knowledge of Architects in the construction industry in Saudi Arabia
- Develop a framework for construction knowledge of Designers in the construction industry in Saudi Arabia
- To investigate whether the knowledge level affects the design package.

1.4 Significance of Study

The objective is to furnish a comprehensive comprehension of the significance of designer proficiency and its impact on the success of a project. The present study investigates the multifaceted nature of designer knowledge and its impact on the performance of construction projects. Specifically, the research delves into the designer's proficiency in comprehending clients' requirements and translating them into design solutions, their expertise in materials and construction techniques, and their aptitude for communicating with other stakeholders involved in the project.

This thesis aims to delineate the obstacles that designers encounter in their pursuit of producing superior work and propose plausible remedies to enhance their efficacy. This thesis offers valuable perspectives on how Saudi Arabia can improve the performance of construction projects through the allocation of resources towards designer education and training.

This research project also provides recommendations on how designers may obtain appropriate construction knowledge that will allow them to design safer and more efficient projects. The extant literature pertaining to designer knowledge and its impact on project performance (design package) is relatively abundant in Western regions. However, in the developing areas of North Africa and the Middle East, academic investigations on this subject are infrequent. This study aims to address the aforementioned knowledge gap in the Saudi Arabian construction industry by conducting an analysis of area A/E firms that have experienced a decline in the expertise of their professionals and examining the impact of this decline on construction project performance. The Kingdom of Saudi Arabia is presently experiencing significant changes in its revenue streams, which have undergone diversification and now serve as a substantial source of government support.

The inception of Vision 2030 was initiated in 2016. The local market across various industries in Saudi Arabia has encountered several challenges in adapting to the objectives of the vision, as noted by Banawi (2017). The present research enhances the existing body of knowledge by conducting an analysis of the subject matter. The findings of this study can assist contractors and consultants in making informed decisions regarding the implementation of academic programs and/or intensive training sessions aimed at enhancing the proficiency of designers prior to project commencement.

Thus, this study aims to provide assistance to executive managers and management councils of construction firms and consulting offices in Saudi Arabia through the following means:

This study aims to facilitate stakeholders in achieving their objectives.

1. The objective is to determine the key factors that impact the extent of construction knowledge possessed by designers.
2. Identifying the prevailing factors that contribute to the deficiency or abundance of knowledge.
3. Reducing the adverse effects of insufficient knowledge in the field of construction.
4. Enhancing the efficiency of the knowledge management process.

In the event that the study demonstrated a deficiency in the designer's knowledge, it can be inferred that further research and education may be necessary to address this issue. There are various strategies that can be implemented to augment the knowledge of designers. An effective strategy involves implementing designer-oriented training and development initiatives that concentrate on particular competencies and expertise pertaining to building undertakings. Participating in professional development activities, such as attending workshops, seminars, and conferences, can offer significant benefits by providing insights into current industry trends, optimal methodologies, and emerging technologies.

An additional approach involves promoting continuous education among designers by means of professional organizations, virtual communities, and various networking platforms. Collaborative work environments have the potential to enhance the knowledge of designers by facilitating opportunities for learning and growth through interactions and feedback from peers. Finally, the act of documenting lessons learned from previous projects can facilitate designers in acquiring knowledge from their past experiences and circumventing the repetition of identical errors in subsequent endeavors. Through the implementation of these strategies, construction firms have the potential to augment the expertise of designers and enhance the overall performance of their projects.

1.5 Scope & Limitations

Specifically, this study aims to evaluate the effects of Designer's Construction Knowledge's on performance of construction projects in Saudi Arabia. Hence, this study is limited to prominent consulting firms that specialize in the creation of building structures and are situated in the Eastern Province of Saudi Arabia. To delimit the research scope, it was restricted to designers instead of encompassing all design professionals. and generalizing the results to other industry sectors may be questionable. Moreover, the data is gathered from consulting offices that were classified as excellent by Saudi Council of Engineers (SEC) and the Contractors Rating Agency (tasneef).

The analysis was limited to designers in Grades 1 and 2. In addition, in order to ensure the validity of the findings, it was imperative that the consultancy offices and contractors under scrutiny possess expertise in the field of building construction, due to time and cost constraints, the study is done only in the eastern province of Saudi Arabia.

Another limitation of the study is the focus solely on the impact of Designer's Construction Knowledge on project performance, without considering other critical aspects of the project process. Factors such as project management methodologies, client requirements, procurement strategies, and external environmental factors play significant roles in project outcomes but were not addressed in this study. Consequently, the findings may lack a comprehensive understanding of the broader project dynamics, potentially limiting the applicability of the results to real-world construction projects beyond the scope of designer knowledge.

1.6 Thesis Organization

The following chapters will be included in the proposed thesis:

- Chapter 1, titled "Introduction," provides a comprehensive overview of the research topic, its scope, objectives, and significance.
- Chapter 2, titled "Literature Review," provides an extensive review of the existing literature pertaining to the research topic.
- Chapter 3, titled "Research Methodology," outlines the various steps and phases involved in the current research project.
- Chapter 4, titled "Result Discussion," interprets the results obtained from the questionnaire survey.
- Chapter 5, titled "Conclusion and recommendations," summarizes whole study, draws conclusions based on the outcomes of the research, and outlines the recommendations for future development and improvement.

CHAPTER 2

LITERATURE REVIEW

This chapter gives a summary of the material gathered throughout the project's literature review.

2.1 A Brief History of Construction

The master builder once occupied a prominent position in society and was responsible for the conception, funding, design, and construction of historic buildings and improvements. These individuals were highly esteemed, and their ideas in the public sphere were unequaled. The master builder does not exist in its original form anymore. The notion of the master builder has been utilized throughout history but is most commonly linked with the Renaissance. According to the University of Colorado's (n.d.) design-build lexicon, historically, a master builder was responsible for the design and building of a project. Throughout the Renaissance, a distinction existed between the person who created the project's design and the person responsible for its construction. With the development of design professionals in the late 19th century, the phrase went out of popularity and is now seldom used to describe design/build organizations. (Flavell, 2011).

Master builders were experts in both the sciences and construction. During the Renaissance, collective knowledge was far more limited than today; certain people were regarded to know everything. Individuals who succeed in several professions are still referred to as "Renaissance men," One of the most outstanding originals, Leon Battista Alberti, a contemporary of Leonardo da Vinci, remarked that "a man may do all things if he so chooses." Renaissance humanists thought humans had an inexhaustible capacity for progress and should maximize their potential (AnswerBag 2008).

The concept that humans can know everything and eventually control everything about their environment is opposed to the prevailing viewpoint. With today's politically correct mentality, all things environmental are to be treasured, and individuals should not mess with or alter natural processes. The environmental movement does not acknowledge current technical marvels that harness the environment for the benefit of humans, yet ancient civilizations treasured similar exploits. (Flavell 2011).

Beginning with the advent of the Industrial Revolution, design-build went out of favor for some time. The construction industry's primary concern was meeting customer demand rather than improving the standard of its work. In addition, because creating industrial buildings requires a high level of technical ability, architects and interior designers need different talents than construction workers. As a direct consequence, the designers and the constructors were split off. The owners started by commissioning an architect to create a design for them, and then they put the construction job up for bids. This approach is known as plan-spec, sometimes known as design-bid-build.

There are repercussions resulting from the split between the designer and the builder. Because owners have separate contracts with designers and builders, they manage specific deadlines and receive separate information from each group. As a direct consequence of this, owners expend a more significant amount of time and effort supervising building projects. When errors occur in a construction project that uses the design-bid-build method, the architect and general contractor are ready to point the finger at one another. The architect and the constructor believe that the owner should be responsible for the costs where there is disagreement about who is to blame.

Design-build projects comprise about forty percent of all non-residential building and design projects (dbia.org 2022). Because of its significant advantages, design-build has become an increasingly popular option for owners who seek cooperation, high-quality construction, and rapid completion of their projects. It has been 25 years since the Design-Build Association of America was established to advance design-build as a system of construction delivery and define its most effective practices.

2.2 Designer Construction Knowledge

Construction and engineering professionals have found it more challenging to learn from their mistakes, particularly concerning avoiding, detecting, and containing design faults. John. et al. (2001) emphasized that the bulk of structural failures and related damage costs result from mistakes in planning, design, construction, and use, as opposed to variations in construction material, strength, and structural loads. It should be recalled that design is the initial stage of construction and that design errors have been the root cause of countless catastrophic incidents that have resulted in the death and injury of employees and members of the public.

There are substantial design quality issues when flaws, omissions, and ambiguities in plans and specifications become apparent during construction (Davis & Ledbetter, 1987). Due to design or construction flaws, a substantial percentage of the nation's maintenance budget is allocated to corrective or corrective actions for buildings and their services.

This body of work investigates the effect of design errors on construction projects by determining the different design errors that already exist in building and civil construction projects. It then investigates the causes of design errors in construction projects, evaluates the impact that design errors have on construction projects, and suggests solutions to reduce the amount of uncertainty caused by design errors.

The now enormous volume of design information, which is beyond the capability of any one person to possess] has led to the split of the job of master builder into devoted specialized specialties (Bucciarelli, 1994). In addition, considering the escalation in complexity of the delivery of building projects (Fischer et al. 2017), a high degree of collaboration, cooperation, and coordination within the design and engineering processes has become unavoidable (Kleinsmann, 2006). Design management was developed in response to these difficulties (Emmitt, 2014).

Many enduring issues in the construction sector are directly or indirectly attributable to evil designs, design processes, and design management (Biotto, 2019; Knotten, n.d.). According to Love and Li (2000) and Love et al. (2008), design flaws have been the leading factor of building and infrastructure failures as well as project schedule and expense overruns" and fatal accidents and injuries during building construction and operation (Chapman, 1998). Lopez et al. (2010) posit that the implementation of effective management practices and the establishment of a conducive learning environment for individuals to learn from their mistakes hold the greatest potential for improving building design, given the challenges and intricacies associated with project delivery. However, given the numerous reports on design flaws and failures, it is evident that design management has fallen short of expectations (Borgstein et al., 2018; Knotten, n.d.; Koskela et al., 2018).

According to Kannengiesser and Gero(2009) and Koskela et al. (2002), poor practices result from the absence of a universally accepted underlying philosophy of design and design management. To put it another way, to progress the practices of building design and design management, one must first comprehend the nature of the activities that comprise design and design management.

According to the findings of this investigation, and in agreement with those of Koskela et al. (2002) and Ballard and Koskela (2009), design and design management are regarded as components of the overarching phenomenon of production, which is defined here as the process of designing and fabricating artifacts. This is permissible because every design is intended to be manufactured, and all artifacts that have been manufactured have been designed. Based on the transformation, flow, and value (TFV) theory of production (management), slim design and lean design management have been created over the past three decades (Ballard et al., n.d.; Koskela, 2000).

Design encompasses technical and social actions that address causality (Koskela et al., 2014) and interpretation (Snodgrass & Coyne, 2013), respectively, due to the generative character of design activity and its embedding within a specific environment. In modern design theory, however, scientists categorize design and design management as technical or social activities. As a result, there is no unifying philosophy of design and design management ((Dilnot, 2018; Koskela et al., 2002).

The role profile is the description of roles that Architects are expected to demonstrate in achieving the outcomes of the Ministry of Works and Human Settlement. It defines outcomes and competencies for an individual role. It concentrates on outcomes rather than duties, which provides better guidance than a job description on expectations. It does not constrain Architects to carry out a prescribed set of tasks as shown in Table 2..

Table 2-1: Architectural Designer Role Specifications

Architectural Designer	▪ Plan, design, manage, and review or oversee construction, development of the built environment for practical, aesthetic, religious, or creative objectives, such as office buildings, theatres, industrial facilities, landscaping, and/or other physical properties. ▪ The task at hand involves scrutinizing the construction and renovation plans of consultant firms to ascertain their functionality, safety, economic viability, and adequacy in meeting the customers' requirements. ▪ Coordinate and/ or liaise with various engineering disciplines such as structural system, air-conditioning, heating, and ventilating system, electrical systems, communication systems, plumbing, utility, site, landscaping, and/or related physical structures.
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The competency is the clustering of key competencies by related behaviors and functions of each role. It comprises a set of Knowledge, Skills, and Abilities (KSA) that result in essential behaviors expected from Architects. The framework has identified six competency areas as follows:

Table 2-2: Architectural Designer Key Competencies

Architectural Designer	▪ Professional and Technical Knowledge ▪ Managerial and Leadership skills
------------------------	---

The key competency is an observable behavior that indicates the presence of the particular competency as shown in table 2.2. Generally, it is broadly divided as core competency, leadership competency and technical or functional competency. The framework has identified few key competencies as presented below:

Table 2-3: Architectural Designer Key Competencies Specified

Architectural Designer	Professional and Technical Knowledge	▪ Knowhow on Architectural Design and construction ▪ Basic knowledge of various Architecture related disciplines such as Engineering, Planning, Landscaping, Interior Design and Conservation. ▪ Aware of architectural related rules, regulations, standards, and codes
	Managerial and Leadership skills	▪ Effective communication and negotiation skills ▪ Teamwork and coordination skills ▪ Management skills (physical as well as emotional)

Table 2.3 shows that the majority of current publications addressing constructability do not stipulate that designers should acquire a certain level of construction expertise before beginning a design career. These sources frequently cite contractors or construction managers as the primary source of information and evaluations regarding constructability. Few references indicate that designers may lack quality construction knowledge, which may contribute to construction delays, failures, and design mistakes.

The American Society of Civil Engineers cited Mr. George Reider of Constructability Consultants, Ltd as saying, “Many design engineers have never been out in the field and cannot visualize the labor and equipment flow required to perform the project”, Paulson also states, " Knowing how to package separate construction contracts along recognized trade and jurisdictional boundaries, as well as accurate knowledge for estimating time and costs for different operations, are essential. Few design consultants really have such capabilities". Uluatam stated in "Civil Engineering Experience and Education": "It can be strongly advised that civil engineering students have at least a total of six months summer practice on a construction site, which will constitute the first experiences of their professional life"

According to "Impact of Design, Construction, and Cost on Project Quality" by Chadwick, a knowledgeable on-site representative of the design firm is "invaluable." Unfortunately, many projects lack an on-site design representative, which eliminates a crucial method for designers to observe the construction process and gain construction expertise. In addition to lacking formal training on construction sites, many architectural and civil engineering students only take a handful of construction-related courses in college. According to Ogelsby, "Most educators in the four-year civil engineering programs admit that their programs do not give much attention to construction".

Saudi Arabia's construction industry has undergone significant transformation over the past two decades. The majority of these modifications may have negatively affected the quality, cost, and duration of construction projects. In particular, the alterations in project delivery systems have had a significant impact on the industry. This research project demonstrates not only how, when, and why these changes have occurred, but also how the industry can enhance designer construction knowledge and project delivery in order to reduce construction project costs, quality, and schedule.

2.3 Designer Knowledge: Roles & Responsibilities

The term "designer knowledge" refers to a collection of aptitudes and proficiencies that a designer has obtained via formal education, professional development, and practical application. The field involves a diverse set of technical and artistic proficiencies, which include expertise in design principles, construction materials, software applications, project coordination, and implementation strategies. The expertise of a designer encompasses not only technical skills but also a comprehension of the social, cultural, and environmental aspects that impact design choices. Additionally, effective communication with clients, stakeholders, and other project team members is a crucial component of a designer's skill set.

The significance of designer expertise in construction endeavors is of utmost importance, given its potential to exert a substantial influence on project efficacy, expenditure, excellence, and security. Insufficient expertise in design can lead to design inaccuracies, project delays, budgetary excesses, and potential safety risks, all of which can have an adverse impact on the project's outcome. Hence, it is imperative that designers maintain a continuous process of updating their knowledge and skills in order to keep pace with the ever-changing demands of the construction industry.

A designer refers to an entity or individual engaged in the creation or modification of designs for construction projects, as well as overseeing or directing others in these tasks. Designs consist of illustrations, intricate design elements, specifications, quantities, and design computations. Designers can take on various roles, such as architects, consulting engineers, quantity surveyors, interior designers, or any other profession that entails the development and alteration of designs. Additionally, designers can be general contractors, specialized contractors, artisans, or even business clients, provided they are actively involved in the design process of the project.

Regulation 9 of the CDM2015 guidance states:

1. A designer may not begin work on a project unless he or she is satisfied that the client is aware of the responsibilities owed by the client under these Regulations.
2. When preparing or modifying a design, the designer must consider the general principles of prevention and any pre-construction information to eliminate, so far as is reasonably practicable, foreseeable risks to the health or safety of any person: a. carrying out or being affected by construction work; b. maintaining or cleaning a structure; or c. using a structure designed as a workplace.
3. If it is not possible to eliminate these risks, the designer must, to the extent that it is reasonably practicable:
 - a. take steps to reduce or, if that is not possible, control the risks through the subsequent design process.
 - b. provide information about these risks to the principal designer; and
 - c. ensure that the health and safety file contain pertinent information.
4. The designer must take all reasonable measures to provide, with the design, sufficient information about the design, construction, and maintenance of the structure to assist the client, other designers, and contractors in fulfilling their responsibilities under these Regulations.

The decisions of a designer can affect the health and safety of everyone involved in the construction, use, maintenance, refurbishment, and eventual demolition of a building.

Before initiating design work, designers must:

- Confirm that the client understands their obligations under CDM 2015. When creating or altering designs:
 - Take into account any pre-construction information provided by the client (and principal designer, if applicable).
 - Aim to eliminate all foreseeable health and safety risks for those impacted by the project, if possible.

- Minimize or manage hazards that cannot be removed or reduced. Supply design information to:
 - The principal designer (if involved) for integration into the pre-construction information and the health and safety file.
 - The client and principal contractor (or the contractor for single-contractor projects) to support their compliance with responsibilities, such as ensuring the preparation of a construction phase plan (PDF).
- Engage in communication, collaboration, and coordination with:
 - Other designers (including the principal designer) to guarantee compatibility of designs and health and safety, both during the project and in the future.
 - All contractors, including the principal contractor, must factor in their knowledge and experience with building designs.

2.4 Project Performance

The construction industry is a dynamic, multifaceted field that demands expertise in a range of areas, from planning to execution. In this context, the role of the designer is crucial, as their knowledge and skills are fundamental to ensure that a project meets its objectives. Project performance is a key factor in the construction industry, encompassing aspects such as time, cost and quality. In order to achieve optimal project performance, designers must possess a diverse set of technical and practical knowledge that allows them to develop effective plans and strategies.

In this thesis, we will explore the relationship between project performance and the designer's knowledge, paying particular attention to the variables of time, cost, and quality. Through this analysis, we will gain a deeper understanding of the complex dynamics that underpin project delivery, and the role that designers play in achieving success.

The importance of designer knowledge cannot be underestimated in project performance. Designers are responsible for translating the client's requirements into functional and aesthetically pleasing structures. They must understand the project's goals, constraints, and technical specifications to create an appropriate design that meets the required standard. Inadequate designer knowledge can significantly affect a project's performance by leading to design errors, delays, or quality issues.

A knowledgeable designer can anticipate potential problems and design solutions to mitigate them, resulting in better project outcomes. Moreover, a designer's expertise can help control costs by designing structures that are efficient in terms of construction and energy usage. Therefore, it is essential for project managers to ensure that designers have sufficient knowledge and experience to create designs that meet the project's objectives, comply with regulations, and are cost-effective. In conclusion, the ability of a designer to apply their knowledge to the project is critical to achieving project performance goals.

When discussing project performance in the construction industry, it is important to consider three main variables: time, cost, and quality. Time refers to the timeline for completing the project, from the initial planning phase to the final delivery. Cost refers to the financial resources required for the project, including materials and labor. Quality refers to the standard of workmanship and the degree to which the finished project meets the client's specifications and standards. All three of these variables are critical for ensuring a successful project outcome.

A project that is completed on time but over budget or to a low quality standard is not considered successful. Similarly, a high-quality project that exceeds the timeline or budget is also considered a failure. Effective project management requires balancing these variables carefully, making trade-offs where necessary to ensure that the project is completed successfully and meets the client's expectations. In conclusion, project performance in the construction industry is significantly related to the designer's knowledge.

A designer with sound knowledge in the construction industry will make informed decisions that will determine project success. The variables that impact project performance are time, cost, and quality, and a proficient designer will handle these attributes with efficiency. They must ensure that the project meets the standard set by the stakeholders and satisfies the needs of the end-users. The designer must understand the client's requirements and translate them into actionable tasks for the project team.

The final output must meet the expectations of all the stakeholders participating in the project. While knowledge is an essential attribute, experience shapes the designer's efficiency. Therefore, it is critical that the designer has exposure to various projects and industries to broaden their understanding and increase their expertise in project design. Ultimately, the designer's knowledge and experience can optimize project performance in quality, time, and cost.

2.5 Project Performance Factors

Time as a variable

Time is a critical variable for project performance due to its potential impact on the overall project's schedule, quality, and cost. A delay in the project schedule can result in increased costs and a decline in quality. Therefore, project completion within the specified time frame is crucial to ensuring that the end-users' needs are met. By employing scheduling techniques, such as critical path analysis, project managers can identify key tasks that need timely completion to meet the project deadline.

Time management is essential for construction projects because time delays are the most common causes of project failure. To address this issue, project managers must develop strategies to manage uncertainties that may arise during the project execution phase to keep the project on track. Such techniques include the use of project control mechanisms and forecasting tools that ensure timely completion. Ultimately, successful project delivery

depends on the ability of project managers to utilize time effectively, maintain control over the schedule, and remain responsive to changes in the project environment.

Time is an essential factor in project performance, especially in the construction industry. Delays in construction can result in increased costs, reduced quality, and a negative impact on project stakeholders. The timely completion of a project is vital because it can impact the overall project performance, it can affect the project's financial viability, and can have an impact on other projects that the firm has planned. The construction industry heavily relies on time-efficient scheduling and project delivery methods to maintain a competitive advantage over rivals in the market.

Efficient time management is critical for project managers to ensure that the project is delivered on time, within budget, and to the client's desired level of quality. Therefore, industry professionals should possess the necessary skills and knowledge to manage time effectively in the construction industry. Additionally, they should be able to develop strategies that will ensure optimal time management throughout the project lifecycle, from initiation to closure.

In summary, the level of designer knowledge has a significant impact on project timelines in the construction industry. Designers who possess a higher level of technical expertise and knowledge are better equipped to address complex project requirements and respond to unforeseen challenges in a timely manner. They can develop more efficient construction plans, make more informed decisions, and coordinate with other project stakeholders more effectively, which ultimately leads to shorter project timelines.

However, the cost of hiring a highly knowledgeable designer may be higher, which can offset any potential savings from reduced project timelines. Thus, project managers must weigh the benefits of hiring a designer with advanced technical knowledge against the costs associated with doing so to determine the optimal design team configuration for a given project. Additionally, it may be useful to provide designers with ongoing training and

development to keep their knowledge and skills updated, ensure that they stay updated with the latest technological advancements, and ultimately improve project performance.

Cost as a variable

When it comes to project performance, cost is a critical variable that must be considered carefully. Managing costs often means trading them off against other variables, such as time and quality. Some designers may focus solely on creating the most aesthetically pleasing project possible without considering the cost implications. However, projects that are over budget can lead to significant delays and ultimately inhibit the ability to deliver quality results on time. This is why designers must weigh the cost of a project against other variables and prioritize them while designing.

Cost management strategies, including value engineering, cost-benefit analysis, and earned value management, can help ensure that projects stay on budget without sacrificing quality or delivery times. By recognizing the role of cost in project performance, designers can make informed decisions and deliver successful project outcomes.

Cost management is a critical aspect of the construction industry, and it involves identifying, assessing and controlling project costs. When a project is not correctly managed, the costs can skyrocket, leading to budget overruns, inconclusive designs and poorly executed projects. As such, cost management is a crucial determinant of project performance that should not be ignored. It allows project managers to streamline costs, optimise resources and keep project expenses within the budgeted figure. Proper cost management techniques can help to identify waste, cost leaks and inefficiencies, which, when resolved, can have a significant impact on the project's success. Hence, cost management is essential for project performance and should be prioritized from the project design phase through to completion. With effective cost management practices, construction industry teams can mitigate against budget overruns and other financial issues to deliver quality projects within the scheduled timeline and within budget.

Good design can save a project money, while poor design can lead to cost overruns. This is because designers have the ability to identify opportunities for value engineering. Value engineering is the process of taking a critical look at the project and finding ways to reduce costs without compromising quality. Designers can recommend cost-effective materials and construction techniques. They can also design buildings with energy efficiency in mind, which can result in long-term cost savings for the owner.

Designers also have the ability to identify potential construction challenges early on and incorporate solutions into the design. This can prevent costly change orders and delays later on in the project. By understanding the impact of their design decisions on project costs, designers can play a critical role in keeping the project on budget.

Quality as a variable

Quality is a variable that must always be taken into account when evaluating project performance, especially within the context of the construction industry. Good quality ensures that the project fulfils its intended purposes and is sustainable over time. It reflects clients' satisfaction and protects the reputation of designers and contractors.

Studies have shown that quality issues are usually caused by inadequate attention to detail, poor communication, insufficient quality control and suboptimal collaboration between project stakeholders. Quality has been found to be correlated with both cost and time, as fulfilling quality expectations inevitably takes time and resources. Therefore, achieving quality requires a balance between these three variables. Whilst ensuring that cost and time targets are met, the designer and contractor must take an iterative approach to continually improve quality whilst minimizing costs and time constraints. This approach is particularly essential in an industry where the smallest mistakes can have the greatest consequences.

A significant aspect of effective project management is quality control. Quality control refers to the processes and activities that are implemented to ensure that a project meets the required standards of quality. Quality control measures include the identification of quality goals and objectives, the establishment of quality standards, and the continuous monitoring

and evaluation of the project progress against these standards. A comprehensive quality control program can help to reduce the risk of project failure by ensuring that the project meets the expectations and requirements of all stakeholders involved. In the construction industry, quality control is especially important as it involves the safety of workers and public, efficiency, and durability of infrastructure.

Quality control should be viewed as a critical component of project management rather than an additional and optional task. By implementing an effective quality control program, construction project managers can ensure that their projects are completed on time, within budget, and to the required standards of quality, ultimately leading to satisfied stakeholders and long-term success.

One of the essential aspects that ensure high-quality project performance in the construction industry is the designer's knowledge. The designer's knowledge includes their education, experience, and expertise in designing structures that meet building standards and regulations. A designer with extensive knowledge of building codes, materials, and technology can help ensure that the project is constructed safely and efficiently.

Moreover, the designer's knowledge can significantly contribute to the project's quality by anticipating potential problems during construction and providing solutions that maintain design intent and quality. Without the designer's knowledge, the project may encounter design errors, safety concerns, and sustainability issues that can result in delays, cost overruns, and poor-quality outcomes. Therefore, it is vital for the project team to select designers with comprehensive knowledge and expertise in their chosen field to increase the likelihood of producing high-quality project performances that meet cost, time, and quality objectives.

In conclusion, it is evident that the designer's knowledge plays a critical role in project performance in the construction industry. The study has identified time, cost and quality as the major variables for project performance in construction projects. However, the literature review also highlights that the designer's knowledge positively influences the performance of the project in each of these areas. The findings suggest that the designer should have in-depth knowledge and expertise in the field to ensure that the project is completed within the stipulated budget, timeline and with high-quality standards.

Additionally, it is recommended that the designer be involved in every stage of the project, from conception to completion, to monitor and ensure that all aspects of project performance are addressed. By placing a strong emphasis on the designer's knowledge, construction project owners and managers can optimize performance and achieve successful outcomes. With the constant technological advancements, it is not difficult to envision a future construction industry where knowledgeable designers play a vital role in ensuring project performance. With a focus on transforming construction processes and techniques, smart infrastructure, and designing for sustainability, knowledgeable designers can play an essential part in reducing project cost and timeline while improving overall project quality and durability. Such designers may also use innovative technology like Building Information Modelling (BIM), which can help improve the coordination process among stakeholders in construction projects, ultimately reducing conflict and keeping all parties accountable.

Additionally, knowledgeable designers' ability to utilize virtual reality and augmented reality can result in clearer designs that better align with project stakeholders' expectations and help mitigate project risks. Therefore, it is crucial that construction firms align their hiring and training strategies to ensure they have access to knowledgeable designers capable of driving future construction innovation, including improved project performance.

2.6 Designer Knowledge effect on Project Performance

Both the actions and decisions of an organization are significantly influenced by its level of knowledge. Consequently, the effectiveness of knowledge management is intrinsically linked to the accomplishment of an organization's goals. This serves to illustrate why companies are investing more and more in knowledge asset management. Among the most frequently cited reasons for such investments are the enhancement of an organization's capabilities, the promotion of performance efficacy, and the improvement of decision-making through the strategic application of knowledge assets.

These knowledge assets may be investigated independently or as a concept for the knowledge management system (Yeong, 2010). In the context of project management, essential success factors are a list of areas or a collection of variables that a project manager must be knowledgeable about in order to generate a successful project (Verburg et al., 2013). Fortune and White (2006) enumerated a list of critical success factors that knowledge management activities may influence, including:

- Support from senior management;
- A capable project manager;
- Skilled and trained staff/training provision;
- Learning from previous experience;
- Departmental understanding;
- Good communication/feedback;
- Organizational adaptation/culture/structure;
- User/client involvement;
- Consultant involvement

Construction firms are becoming more competitive with low profit margins as the construction industry grows in importance as a result of rapid urbanization in developing countries (Ali et al., 2018). Since construction organizations are believed to be information-intensive and experience-based institutions that rely on the sharing and incorporation of their professionals' accumulated expertise, knowledge management is increasingly recognized as a crucial capability for construction organizations to gain a competitive edge (Oti et al., 2018).

Due to the prevalence of project-based activities in the construction industry, project participants are considered knowledge repositories. Turnover of team members results in a lack of project experience, increases the risk of reinventing the wheel, and consequently reduces the success of the project (Ajmal et al., 2010; Yang et al., 2020). Consequently, the ephemeral nature of construction initiatives necessitates effective knowledge transfer, transition, and incorporation in order to address issues. Moreover, a construction project's complexity and multiple phases necessitate cross-functional team collaboration during project execution (Sun et al., 2018).

(Takhtravanchi & Pathirage, 2018) Knowledge management among members with diverse professional knowledge at various stages is crucial for effective and seamless implementation. Numerous reports have emphasized the importance of knowledge management; however, low profit margins and the conservative nature of construction firms continue to present obstacles, such as a lack of time and funding, a non-adherence to standard processes and facilities, a competitive organizational culture, and employee resistance (Yang et al., 2014). Due to the method of performance evaluation, project managers place a greater emphasis on project costs and duration than on the intangible potential benefits of knowledge management.

There is insufficient documentation and ad-hoc distribution of results, rather than a live process (Sun et al., 2018), despite the fact that some construction companies claim to study lessons at project closeout. Some construction firms are currently attempting to implement knowledge management systems, but the potential benefits are not compelling to all stakeholders because implementation requires significant financial and human capital, which are not the firm's core competencies (Yang et al., 2014).

Moreover, distinct thinking worlds and a lack of shared knowledge among multidisciplinary members of the construction project team not only necessitate knowledge integration, but also present a number of challenges (Kyriazis et al., 2017). Consequently, there is a pressing need to promote knowledge management, particularly knowledge integration in construction initiatives with such limited resources.

Governance structures and knowledge processes (e.g., assimilation and incorporation of knowledge) are required for knowledge management. According to knowledge management studies, corporate governance structures such as organizational structure, rewards, and routine can be used strategically to improve knowledge-based processes of development, transition, incorporation, and sharing (Foss et al., 2010).

As a consequence, it provides a method for enhancing the implementation of knowledge management. In addition, the incorporation of knowledge within an organization is the essence of organizational capacity, which provides a natural justification for the knowledge governance perspective. Consequently, project management skills, which are essential organisational competencies in project-based construction organizations, can also be viewed as governance tools that can be used to enhance knowledge alignment execution in construction projects (Demirkesen & Ozorhon, 2017).

Knowledge management factors in construction project performance

Project management is one of the most crucial aspects of construction projects because it determines the objectives, timelines, and strategic activities to mitigate risk and allocate resources (Papke-Shields & Boyer-Wright, 2017). Several studies indicate that knowledge management plays an essential role in project management performance. This study applies the following four knowledge management dimensions.

2.6.1 Knowledge Process

There are three fundamental knowledge processes, according to Firestone and McElroy (2002): information development, knowledge validation, and knowledge integration. Information development corresponds to knowledge generation, capture, and sharing because it involves the generation of new ideas and insights (generation), the acquisition of skills from external sources (capture), and interpersonal interaction (interaction) (sharing). Validation of knowledge is a transitional phase in the knowledge life cycle because it involves assessing the practical value of knowledge. The third dimension is knowledge integration, which requires codification and a method of transition. Knowledge integration refers to the application of knowledge within an organization.

2.6.2 Knowledge Technology

Numerous businesses invest in technology to obtain a competitive advantage and boost their overall efficacy. However, the function of technology and its impact on project achievement are contingent on how an organization develops its technical systems. Technology is not the only method to increase project efficiency, but it provides project managers with a number of advantages that can make their tasks easier. Therefore, knowledge management technology is required to enhance the overall performance of the organization. Despite the fact that technology has enabled managers to make sound hiring decisions, the human element remains and has frequently led to discrimination (Anantatmula, 2008; Lindner, & Wald, 2011; Lundin & Lund, 2016; Kane, 2017).

2.6.3 Knowledge Culture

According to Agamuthu and Fauziah (2011), the relationship between knowledge culture and project performance is robust. The five components of information cultures that support the dependencies of project management performance are empowerment, internal and external orientations, improvement orientation, and human resource orientation, according to Van den Berg and Wilderom (2004). Knowledge culture encourages proactive competition orientation, effective challenger coordination, and professional information management; consequently, employees who achieve a competitive advantage are compensated (Aliyu et al., 2015).

2.6.4 Knowledge Leadership

According to Kiioh (2015), it is essential to have knowledgeable leadership to ensure the successful implementation of information technology on initiatives. There is a strong correlation between project management advancement and leadership in project implementation, with leadership having the greatest impact on project effectiveness.

2.6.5 Knowledge Acquisition

Knowledge acquisition is a crucial factor in knowledge management, playing a significant role in the effective utilization of organizational knowledge. It refers to the process of capturing, acquiring, and acquiring new knowledge from various sources, both internal and external. Knowledge acquisition involves identifying relevant information, extracting valuable insights, and transforming them into usable knowledge within the organization. This process includes activities such as conducting research, collecting data, analyzing best practices, leveraging expertise, and fostering a culture of continuous learning. By prioritizing knowledge acquisition, organizations can enhance their knowledge base, facilitate innovation, improve decision-making, and ultimately drive overall organizational success.

2.6.6 Knowledge Sharing

Knowledge sharing is a fundamental factor in knowledge management, playing a vital role in maximizing the value of organizational knowledge. It involves the dissemination of knowledge, information, and expertise throughout the organization, enabling individuals and teams to access, use, and build upon existing knowledge. Knowledge sharing promotes collaboration, fosters a learning culture, and facilitates effective problem-solving and decision-making. It can take various forms, including formal processes, such as documentation and training programs, as well as informal channels, such as conversations, communities of practice, and online platforms. By encouraging and facilitating knowledge sharing, organizations can harness the collective intelligence of their employees, enhance innovation, improve productivity, and achieve sustainable competitive advantage in today's knowledge-driven economy.

2.6.7 Knowledge Retention

Knowledge retention is a crucial factor in knowledge management, aimed at preserving valuable organizational knowledge for future use. It involves capturing, storing, and maintaining knowledge within the organization to prevent loss of critical information and expertise. Knowledge retention strategies may include documentation, creating knowledge repositories, mentorship programs, succession planning, and employee training and development initiatives. By effectively retaining knowledge, organizations can mitigate the risks associated with knowledge loss due to employee turnover, retirement, or other factors. Retained knowledge serves as a foundation for continuous learning, decision-making, innovation, and overall organizational resilience. It enables employees to access and leverage past experiences, lessons learned, and best practices, thereby enhancing productivity, efficiency, and competitiveness.

2.6.8 Knowledge Education

Knowledge education is a vital factor in knowledge management, focusing on equipping individuals with the necessary skills and knowledge to effectively create, acquire, share, and apply knowledge within an organization. It involves training programs, workshops, seminars, and other educational initiatives that aim to enhance employees' understanding of knowledge management principles and practices. Knowledge education helps individuals develop competencies in areas such as critical thinking, problem-solving, collaboration, information literacy, and technological proficiency. By investing in knowledge education, organizations can promote a culture of continuous learning, empower employees to contribute to knowledge management efforts, and foster innovation and creativity. It enables employees to become active participants in knowledge processes, leading to improved decision-making, increased productivity, and the overall success of the organization.

2.6.9 Knowledge Financing

Knowledge financing is an important factor in knowledge management, as it involves allocating resources and investments to support the acquisition, development, and utilization of organizational knowledge. It encompasses the financial resources dedicated to knowledge-related activities such as research and development, training programs, technology infrastructure, knowledge sharing platforms, and knowledge retention initiatives. Adequate financing is crucial for organizations to effectively manage and leverage knowledge assets, as it enables the implementation of strategies and initiatives that drive knowledge creation, capture, dissemination, and application. By allocating resources to knowledge management, organizations can foster a culture of learning, innovation, and continuous improvement. Furthermore, strategic investments in knowledge financing can lead to improved organizational performance, increased competitiveness, and long-term sustainable growth.

2.6.10 Knowledge Quality

Knowledge quality is a critical factor in knowledge management, focusing on the accuracy, relevance, reliability, and usability of organizational knowledge assets. It entails ensuring that the knowledge captured, stored, and shared within the organization is of high quality and meets the needs of users. Knowledge quality involves processes such as knowledge validation, verification, and review to assess the reliability and credibility of the information. It also includes efforts to eliminate redundancies, update outdated knowledge, and ensure that knowledge is easily accessible and understandable to users. By prioritizing knowledge quality, organizations can enhance decision-making, problem-solving, and innovation. High-quality knowledge promotes efficiency, minimizes errors, and fosters a culture of trust and credibility within the organization. Ultimately, it enables employees to make informed decisions, drive organizational performance, and achieve strategic objectives.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter outlines the essential actions required to achieve the objectives outlined in chapter one of this study. It describes the methods utilized to capture the necessary data for the analysis. In addition, the methodologies for extracting information from the data will be explained in depth. In conclusion, this chapter serves as a road map for the researcher to efficiently complete the proposed study. Methodologies and procedures utilized for this research endeavor are described in the sections that follow. The hypothesis that that designers have had diminished construction knowledge and if this diminished construction knowledge had effects on construction projects performance.

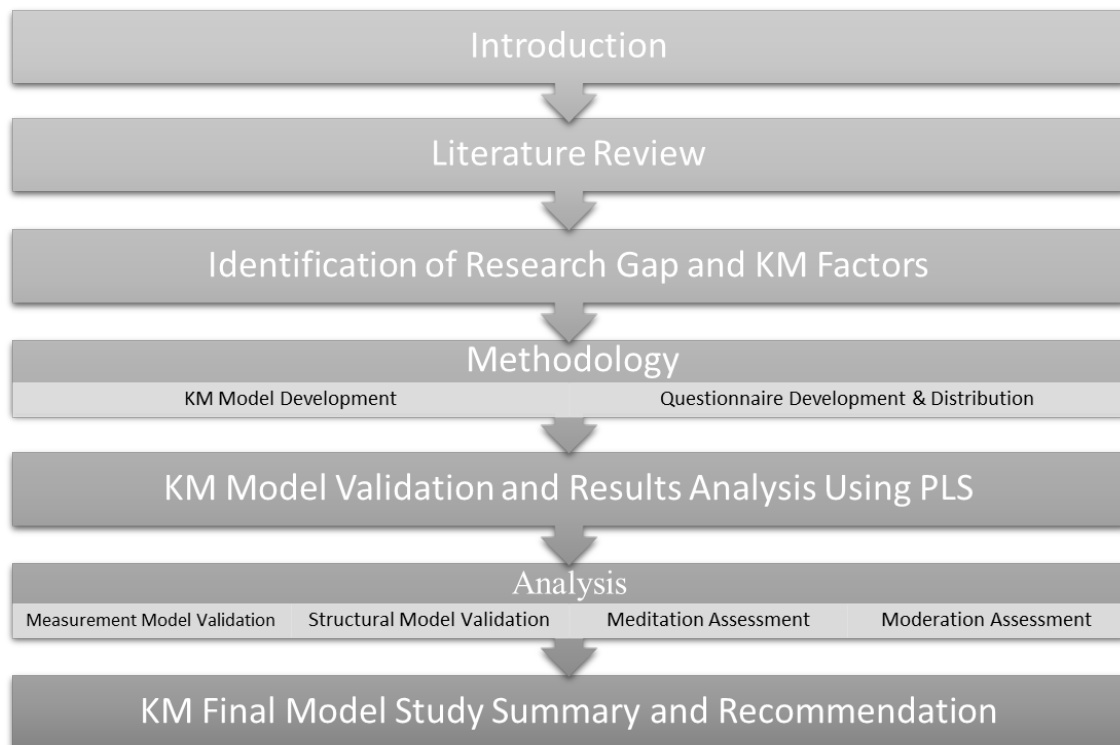


Figure 3.1: Research Methodology]

As the flowchart Figure 3.1 portrays, the aim was to investigate the effect of Designer Construction Knowledge on project performance in the construction industry. The research began with an extensive literature review to understand the existing knowledge in the field and identify research gaps related to Designer Knowledge. Based on the identified gaps, it was possible to develop a comprehensive Designer Knowledge framework and to design a questionnaire to collect data from industry professionals. The questionnaire was distributed to a diverse sample of participants, ensuring a wide range of perspectives.

Once the data was collected, The Partial Least Squares (PLS) analysis was employed to validate the Designer Knowledge Framework and analyze the findings. This process involved validating the measurement model, assessing the structural model, and examining both mediation and moderation effects. Through rigorous analysis, it was possible to refine the an initial Designer Knowledge framework and establish a final framework that accurately represents the relationship between Designer Construction Knowledge and project performance in the construction industry.

In conclusion, the study delivers valuable insights into the critical role of Designer Knowledge in enhancing project performance within the construction sector. Based on the study's findings, the key takeaways are summarized and recommendations are made to industry practitioners and for future research. By implementing these recommendations, construction firms can develop more effective leaders and ultimately improve project outcomes.

3.1 Required Data

The research aims to answer how designer knowledge factors affect projects performance through the developed conceptual framework, which defines the necessary data to achieve the set objectives. As portrayed in the section below, the following ten variables are hypothesized to evaluate the relationship between Designer Construction Knowledge and project performance. Each of these constructs is referred to as a "Latent Variable" since it is measured by a series of questions that are reflective of it. The Designer Knowledge is represented with mediators which may affect the project performance. Therefore, the following data was required:

3.1.1 Designer Construction Knowledge (DK)

The degree of construction knowledge designers possess was investigated and a survey of construction industry professionals was used to establish designer knowledge of construction practices and implement these practices during the design phase of projects. The survey was also used to identify how architects and engineers are implementing their construction knowledge and how new industry design professionals are being trained relative to construction techniques and methods. The designer construction knowledge is measured through the following variables:

1. Design Codes Mastery (DK1): Proficiency in understanding, interpreting, and applying relevant design codes, ensuring compliance and adherence to industry standards in the creation of designs.
2. Regulatory Compliance (DK2): Knowledge of and adherence to local, national, and international regulations and building codes governing design practices, ensuring designs meet legal requirements and safety standards.
3. Digital Design Proficiency (DK3): Competency in leveraging digital design tools and technologies, such as CAD (Computer-Aided Design) software, to create precise and visually compelling design representations, Mastery in utilizing BIM tools and methodologies for collaborative and efficient design processes, ensuring accurate representation and integration of design elements.

4. Cultural Sensitivity in Design (DK4): Recognition and incorporation of cultural considerations in design, ensuring designs align with and respect the cultural context of the construction project.
5. Client-Centric Approach (DK5): A focus on understanding and addressing client needs and preferences, incorporating client feedback into the design process to enhance overall satisfaction.
6. Adaptability to Technological Advances (DK6): Openness to adopting and adapting to emerging technologies in the construction and design industry, ensuring designs remain current and aligned with industry trends.
7. Risk Assessment and Mitigation (DK7): The ability to identify potential risks in the design process and implement strategies to mitigate these risks, ensuring the successful execution of design projects.
8. Continuous Learning and Professional Development (DK8): Commitment to ongoing learning and professional development to stay abreast of industry advancements, trends, and evolving design methodologies.

3.1.2 Knowledge Management Mediators

Knowledge Process (KP)

According to Firestone and McElroy (2002), there are three basic knowledge processes which are information development, knowledge validation, and knowledge integration. Information development corresponds to knowledge generation, capture, and sharing because it entails the creation of new ideas and insights (creation), the accumulation of skills from the outside sources (capture), and interpersonal interaction (interaction) (sharing). While knowledge validation, is a transitional phase in the knowledge life cycle since it requires checking the value of knowledge in practice. The third dimension is knowledge integration where it involved codification and transition method. The knowledge integration is the implementation of knowledge in the organization.

Table 3-1: Knowledge Processes Factor [KPF]

KPF1	Provide training/instruction as normal work practices to project team members.
KPF2	Processes for documenting lessons learned are regularly improved and updated.
KPF3	Processes for searching for lessons learned are regularly improved and updated.
KPF4	Ability to provide knowledge that others need.
KPF5	Provide valuable knowledge for carrying out projects.

Knowledge Technology (KT)

Many organizations invest in technology to gain a competitive edge and increase their overall efficiency. However, the role of technology and its effect on project success are dependent on how an organization's technical systems are developed. Technology is not the only way to improve project efficiency, but it gives several advantages to project managers that can be used to make the jobs easier. Thus, it needs to have knowledge management technology to improve the overall performance of the organizations. Even though while technology has provided managers with the ability to make sound hiring decisions, the human element still remains and has often resulted in prejudice (Anantatmula, 2008; Lindner, & Wald, 2011; Lundin & Lund, 2016; Kane, 2017).

Table 3-2: Knowledge Technology Factor [KTF]

KTF1	Make use of technology to access knowledge in performing projects.
KTF2	Use technologies that allow them to share knowledge about projects within or outside the organization.
KTF3	Participate in knowledge management technology activities such as searching, creating and others.
KTF4	Actively share the project knowledge with others using available technology.
KTF5	Encourage other project team members to apply knowledge technology

Knowledge culture (KC)

According to Agamuthu and Fauziah (2011), there is a strong relationship between knowledge culture and project performance. The five components of information cultures which are empowerment, internal and external orientations, improvement orientation, and human resource orientation that support the dependencies of project management performance Van den Berg and Wilderom (2004). With knowledge culture it promotes proactive competition orientation, good challenger coordination, and professional information management are beneficial, and therefore the employees who achieve a competitive advantage are rewarded (Aliyu et al., 2015).

Table 3-3: Knowledge Culture Factor [KCF]

KCF1	Provides tangible incentives to encourage participation in project knowledge management activities.
KCF2	Motivates employees to participate in project knowledge management activities.
KCF3	Rewards employees who create, share, store and use knowledge to perform projects.
KCF4	Values knowledge seeking and problem-solving.
KCF5	Has a high level of trust among employees for sharing project knowledge
KCF6	Encourages project team members to share mistakes about projects openly without the fear.

Knowledge leadership (KL)

According to Kiioh (2015), it is vital to have knowledgeable leadership to ensure the performance of information technology on projects is conducted successfully. There is significant correlation between project management progress and leadership in projects implementation where leadership having the greatest effect on project efficiency.

Table 3-4: Knowledge Leadership Factor [KLF]

KLF1	Organization encourages team members to participate in project knowledge management activities.
KLF2	Organization supports team members to participate in project knowledge management activities.
KLF3	Provide necessary help and resources to participate in project knowledge management activities.
KLF4	Are keen to see that the employees happy to participate in project knowledge management activities.
KLF5	Has sufficient resources in project knowledge management activities.
KLF6	Has sufficient financial resources for building an ICT system to manage project knowledge.
KLF7	Has sufficient skilled project team members to perform project knowledge management activities.
KLF8	Provides time for project team members to perform project knowledge management activities.

Knowledge Acquisition (KA)

To facilitate knowledge creation and acquisition within the construction industry, several factors must be considered. First, organizations should foster a culture of continuous learning and innovation, encouraging employees to actively seek new knowledge and share their expertise with others. Second, the use of information technology tools and platforms can significantly enhance knowledge management efforts, making it easier to capture, store, and distribute information across the organization. Lastly, creating strong networks and partnerships with external entities such as universities and research organizations can facilitate knowledge transfer and collaborative research, leading to the creation of new knowledge and improved practices within the construction industry.

Table 3-5: Knowledge Acquisition Factor [KLF]

KAF1	Processes for sharing lessons learned are widely accepted as part of normal work practices.
KAF2	Strategies for capturing and creating knowledge in construction projects
KAF3	Importance of knowledge acquisition from external sources (e.g., consultants, experts)

Knowledge Sharing (KS)

One key factor in knowledge management in the construction industry is knowledge dissemination and sharing. It is crucial for organizations to have effective strategies in place to ensure that knowledge is shared among employees and stakeholders. This can be achieved through various methods such as training programs, knowledge-sharing platforms, and regular communication channels. By encouraging knowledge dissemination and sharing, organizations can harness the collective intelligence of their workforce and facilitate continuous learning and improvement. This ultimately contributes to enhanced productivity, innovation, and overall project success.

Table 3-6: Knowledge Sharing Factor [KSF]

KSF1	Communication and collaboration techniques for effective knowledge sharing
KSF2	Role of technology in facilitating knowledge dissemination
KSF3	Believe in sharing knowledge with others.

Knowledge Retention (KR)

In the realm of knowledge management, knowledge retention and storage play crucial roles. The retention of knowledge refers to the ability to retain and preserve the valuable knowledge assets within an organization, preventing them from being lost or forgotten. Storage, on the other hand, pertains to the physical or digital means through which knowledge is stored, organized, and easily accessible by individuals within the organization. Both aspects are essential in ensuring that knowledge is effectively managed and utilized to its fullest potential.

Table 3-7: Knowledge Retention Factor [KRF]

KRF1	Methods for storing and organizing tacit and explicit knowledge
KRF2	Importance of capturing lessons learned for future projects

Knowledge Education (KE)

Training plays a crucial role in determining the success of construction projects. The acquisition of knowledge and skills is vital for effective project management and execution. Research has shown that organizations that provide comprehensive training programs to their employees tend to have better project performance. This is because well-trained and educated workers are equipped with the necessary tools and techniques to overcome challenges and make informed decisions. Additionally, ongoing professional development ensures that employees stay updated with the latest industry trends and best practices, further enhancing project outcomes.

Table 3-8: Knowledge Education Factor [KEF]

KEF1	Importance of continuous learning and skill development
KEF2	Training programs for enhancing knowledge management capabilities
KEF3	Team dynamics and their influence on knowledge management practices

Knowledge Quality (KQ)

The quality of information is defined, according to research of Sheriff et al. (2012), as a critical element for the innovation and optimal performance of companies. For this reason, construction companies that have implemented quality management systems, based on ISO 10006 in 2005 and ISO 9001 in 2008, have increased their efficiency, competitiveness (Hoła et al., 2015) and innovation capacity (Pellicer et al., 2014). From a more entrepreneurial perspective, information quality is seen as a corporate asset that aligns information demands with business processes, improving the ability to run a business, its performance and operational efficiency (Sheriff et al., 2012). On the other hand, information quality requires constant rethinking and a holistic view. The first is to ensure long-term competitive advantage and the second is to balance both technologies and the capacity of staff to use and leverage information for more profitable results.

Table 3-9: Knowledge Quality Factor [KQF]

KQF1	Accuracy: Ensuring that the knowledge reflects the actual facts and information
KQF2	Relevance: The degree to which the knowledge aligns with the specific context, goals, and needs
KQF3	Usability: The practicality and applicability of the knowledge

Knowledge Financing (KC)

Knowledge financing is a crucial aspect of knowledge management, involving the allocation of financial resources to support the acquisition, sharing, and application of knowledge within an organization. It encompasses budget allocation, resource planning, cost-effectiveness, ROI assessment, funding sources, risk assessment, performance indicators, and cost-benefit analysis. By strategically managing financial resources, organizations can enhance their knowledge management capabilities and drive innovation, productivity, and overall performance.

Table 3-10: Knowledge Financing Factor [KFF]

KFF1	Cost of hardware, desktop, accessories, and networks
KFF2	Cost of software procurement, implementation, and maintenances
KFF3	Cost of knowledge management and operations

The next step was analyzing the survey results and reporting the results. After the data is collected from the survey process, they need to be examined and analyzed to accomplish the proposed objectives of this study. The first four sections of the questionnaire were qualitatively analyzed using frequency and distribution analysis methods, such as pie charts. Regarding the last section, the data used to develop the statistical analysis model was derived the questionnaire survey where the respondents were the A/E practitioners. The respondents were requested to gauge each of the knowledge factors using 5-points Likert scale that affect the company performance.

3.1.3 Designer Knowledge Effect on Project Performance

Section F of the survey consisted of questions on Knowledge factors that effect on construction project performance. This section consisted of 10 parts, which are the Knowledge Management Factors, and their mediators.

Effect on Quality:

A review of the effect of designer knowledge has on the quality of the project, The knowledge of the designers in design could influence the completeness of the design before work starts on site. This could cause project delays and cost overruns due to adjustments that need to be made to design in order to comply with the new design requirements.

Effect on Time:

A review of the effect of designer knowledge has on the duration of the project, The knowledge of the designers in design could influence the completeness of the design before work starts on site. The practice of segregating design and construction has led to significant

challenges, whereby designs are formulated without regard for their feasibility or cost-effectiveness, adversely impacting project outcomes. The alterations have resulted in issues that may manifest as project delays in finalization and exceeding budgetary limits in construction endeavors.

Effect on Cost:

A review of the effect of designer knowledge has on the cost of the project, The knowledge of the designers in design could influence the completeness of the design before work starts on site. The segregation of design and construction has resulted in significant issues whereby designs are developed without regard for constructability or cost-effectiveness, adversely affecting project performance. The alterations have led to challenges of exceeding budgetary limits, postponing timelines, and reducing efficiency. The combination of the aforementioned factors harms the overall cost of the project.

Table 3-11: Project Performance (Mediators and Variables)

PPPO1	Time: All project tasks were executed according to the predetermined timetable
PPPO2	Cost: The project's overall budget closely matched the initial projections.
PPPO3	Quality: The project deliverables exhibited a high degree of reliability and demanded minimal maintenance.
PPTS1	Process Satisfaction: All participants have had the chance to express their opinions regarding the project's objective or mission.
PPTS2	Execution Satisfaction: The project team expressed contentment with both the project's outcomes and the process of project management.
PPCS1	Project tasks are executed precisely as outlined in the plan.
PPCS2	Pro The project specifications successfully meet their intended objectives. Vide valuable knowledge for carrying out projects.

The Conceptual Framework development

The acquired knowledge from the literature on variables can explain the phenomenon of designer knowledge affecting the performance of construction projects. Besides, the literature also suggested the connections between these variables through many hypotheses and thus, draw a conceptual framework that shows the relationship of these variables. Figure 3.2 is a conceptual framework expressing the relationship between the level designer's knowledge and the project performance.

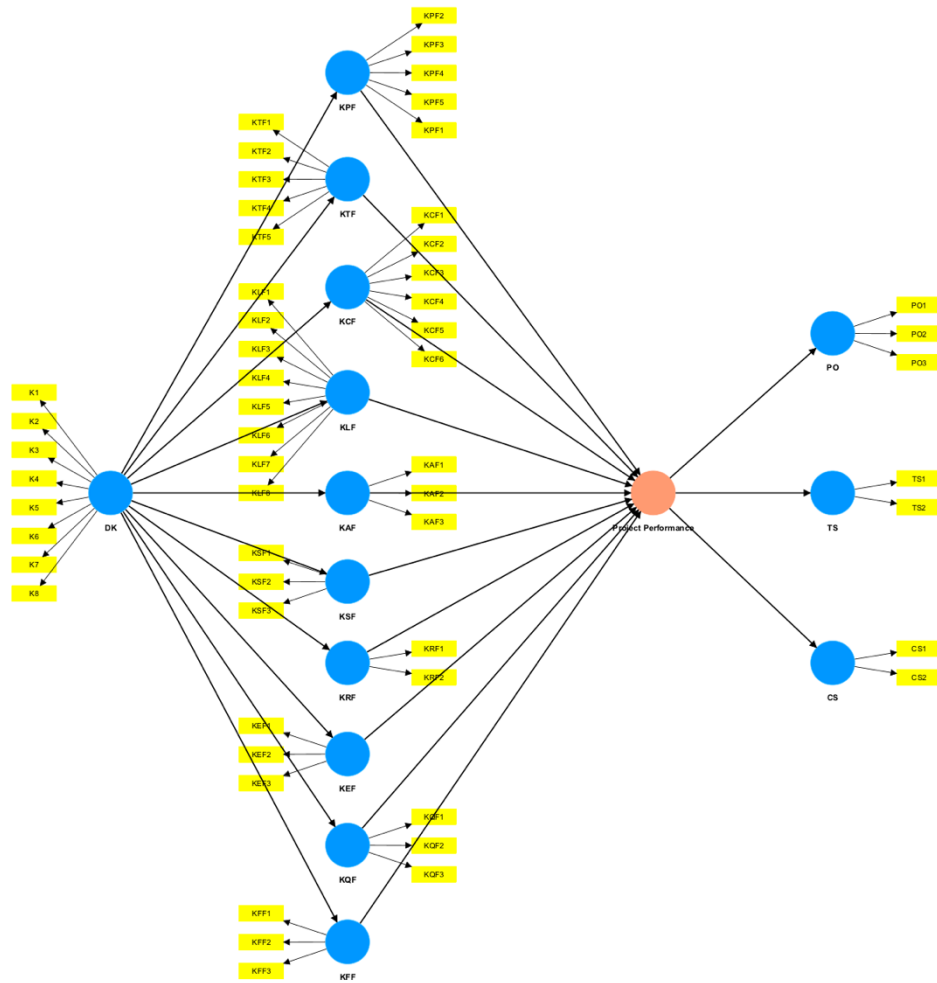


Figure 3.2: Conceptual Framework including Mediators and its Variables (SmartPLS)

3.2 Data Collection

The required data were collected from lead designers who are working in consulting offices classified as excellent. The data were collected through a developed questionnaire. To begin, the researcher has reviewed previous research that examined how the independent variables of the study have impacted other projects. The intensive review of literature has helped to develop a structured questionnaire. The questionnaire consists of three sections and twenty-three questions. The different sections were divided into: 1) demographic questions about the survey participants and the firms they work for, 2) Measuring the Designer Construction Knowledge, 3) Knowledge mediators that has an effect on construction project performance.

Section A of the questionnaire consists of demographic questions on the type of firm, years of employment, level of education, current title/position, professional registration, revenue of the firm and number employees at the firm. The purpose of these questions is to ensure that the respondents came from diverse employment backgrounds. Section B of the survey is dedicated to assessing the level of knowledge possessed by designers in the construction industry. It comprises questions specifically designed to evaluate various aspects of their knowledge, skills, and expertise relevant to the field. This section aims to capture a comprehensive picture of the participants' proficiency in construction design, codes, legislation, regulations, and other pertinent areas. Section C of the questionnaire delves into identifying and understanding the knowledge factors perceived to have an impact on construction project performance. Respondents are asked to provide insights into their perspectives on factors such as leadership, culture, technology, processes, acquisition, sharing, retention, education, financing, and quality. This section is crucial for unveiling the perceived connections between knowledge management and project outcomes in the construction industry, a copy of the questionnaire appears in Appendix A.

The researcher, then, validated the contents of the questionnaire with a panel of judges. As this is a quantitative study, the empirical data were collected and analyzed. Given the aim of this research, which is to validate and assess the suitability of the evaluation model, a quantitative survey was employed. The survey was ultimately distributed to both active and former members of the project team.

This study utilized the survey research method to collect the required data from the key informants in grades 1 and 2 Consultancy Offices. A questionnaire was developed as a tool to collect the necessary data. To attain the goals, a quantitative research methodology was employed in the form of a questionnaire. Quantitative research approaches, as argued by (Harwell 2011) have the advantages of being easily repeatable, producing generalizable results, and are interesting for making predictions. Grahn et al. (2006) argues that a quantitative method involves playing around with numbers. Therefore, this chapter presents the steps that are taken to achieve the objective of the study. The required data, data collection, and data analysis are discussed in the following sections.

- **Population and Sample Size**

The top management of grade 1 and grade 2 consulting offices located in the Eastern Province are the key informants for the necessary data. The Saudi Council of Engineers (SCE) indicates that there are 40+ consultancy offices categorized as grade 1 and 2 within the Eastern Province of Saudi Arabia, they have classified consultancy offices into five grades. The developed questionnaire consisted of two parts. The first part was devoted to collecting data related to the biography of the participants namely, age, gender, level of experience, education level, job title etc. The second part was reserved to ask the indication of the participants about statements related to Designer's Construction Knowledge traits. For this a Microsoft form questionnaire was created and sent to designers via Email, LinkedIn and WhatsApp.

The population of the study is the Grades 1 and 2 Consultancy Offices in the Eastern Province of Saudi Arabia. According to the Saudi Council of Engineers (SCE), these two

grades have 40+ registered Consultancy Offices in Eastern Province of Saudi Arabia based on their annual yearly report posted in 2023. Since, the number of consulting offices were limited and reachable, a consideration of all of them as a population of the research was utilized. The minimum number of Consultancy Offices that are representatives of the population was determined using the following formula (Kish, 1995):

Where:

n_o : Sample size's first estimate.

p : The proportion of the characteristic being measured in the target population.

q : $1-p$

v : The maximum allowable percentage of standard error.

N : The population size.

n : The sample size.

$$n_o = \frac{p * q}{v^2}$$

$$n = \frac{n_o}{1 + \frac{n_o}{N}}$$

To obtain the representative size of population, the value for both " p " and " q " was taken as 0.5. Furthermore, 10% ($v=0.1$) was the maximum standard error allowed in this study. Having a population of 53 Consultancy Offices and applying the previous formula showed that the minimum representative Consultancy Offices needed for this study are 21 Consultancy Offices.

- **Data Analysis Tool**

The collected data was used to assess the validity of conceptual framework through many statistical tools as shown in Figure 4.1. This study employed the Partial Least Square Structural Equation Modeling (PLS-SEM) and used Smart PLS software to obtain the desired statistical measures. This method was chosen for the following reasons:

1. Smart PLS is used for the analysis of the measurement and structural models, which shows that it brings accurate estimations of the paths among variables (Ringle et al., 2012).
2. Smart PLS is an apt statistical technique for analysis of complex relations, exploratory studies, and to test moderation effects (Ringle et al., 2012).
3. Researchers e.g., Bjorvatn & Wald (2018), Chileshe et al. (2018), Khosravi et al. (2020), Klaijnsen et al. (2017), Lindner & Wald (2011) and Yun et al. (2014) have used this approach widely in project management studies to test complex relationships

3.3 Data Analysis Model

The development of the model is based on Structural Equation Modelling (SEM) of Partial Least Square (PLS) technique. Fundamentally, there are two techniques for conducting SEM which are Partial Least Squares Structural Equation Modelling (PLS-SEM) and Covariance-Based Structural Equation Modelling (CB-SEM). PLS technique was selected because it is meant for theory prediction and development. While CB-SEM technique is used for theory testing and confirmation (Hair et al., 2017).

The model is conceptualized according to causes and effects relationships. It is comprised of 10 knowledge management factors affecting the construction project performance. These factors were clustered into ten groups namely Knowledge Management Leadership, Knowledge Management Culture, Knowledge Management Process, Knowledge

Management Acquisition, Knowledge Management Sharing, Knowledge Management Retention, Knowledge Management Education, Knowledge Management Financing, Knowledge Management Quality And Knowledge Management Technology. The ten knowledge management factors' groups formed as exogenous/independent constructs of the model and the only endogenous construct is construction project performance. The hypotheses for this model are as in Table 3.12.

The hypotheses of this model were subjected to testing through the utilization of the bootstrapping function of the SmartPLS software. According to Civelek (2018), the bootstrapping technique involves the derivation of a sample from a sample. The method employed involves generating a considerable quantity of 5000 resamples from the initial sample through a process of replacement, with the aim of computing bootstrap standard errors. These errors are then utilized to derive approximate T-values, which are subsequently employed to evaluate the statistical significance of the structural path (Hauser, Ellsworth, & Gonzalez, 2018).

Table 3-12: Hypotheses

Hypo1	Knowledge Leadership has significant effect on PP
Hypo2	Knowledge Culture has significant effect on PP
Hypo3	Knowledge Process has significant effect on PP
Hypo4	Knowledge Technology has significant effect on PP
Hypo5	Knowledge Acquisition has significant effect on PP
Hypo6	Knowledge Sharing has significant effect on PP
Hypo7	Knowledge Retention has significant effect on PP
Hypo8	Knowledge Education has significant effect on PP
Hypo9	Knowledge Financing has significant effect on PP
Hypo10	Knowledge Quality has significant effect on pp

3.3.1 Measurement Component

The evaluation of the measurement model is conducted based on the established criteria for the evaluation of both the measurement and structural models as shown in figure 3.3. The assessment of the measurement model encompassed an examination of the reliability of the indicators, as well as the presence of convergent and discriminant validity.

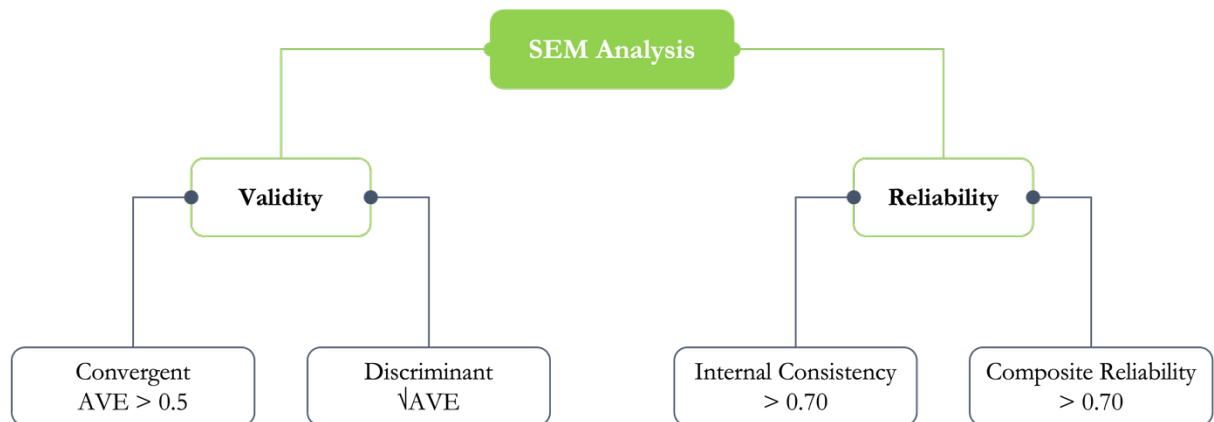


Figure 3.3: SEM Analysis Breakdown

Indicator Reliability

The evaluation of the measurement model in the PLS method entails the confirmation of the validity and reliability of the items, as well as the verification of their convergent and discriminant validity. The reliability of indicators can be determined by calculating the square of the outer loadings of reflective structures. This approach is essential and adequate for evaluating the measurement model and understanding the connection between latent variables and their respective measures. Prior to utilization, it is imperative to confirm that the external loadings of the reflective structures surpass the threshold value of 0.708, which serves as the basis for the indicator's reliability.

Convergent validity

Convergent validity is established when the items within a specific measure converge to accurately represent the underlying construct. The average variance extracted (AVE) is determined by computing the average of the squared factor loadings that correspond to each

indicator of a given construct. Statistical evidence of convergent validity is established when the average variance extracted (AVE) exceeds the threshold of 0.50.

Discriminant Validity:

The study aims to establish discriminant validity in order to ascertain the distinctiveness of its constructs. This suggests that the constructs under investigation possess unique and independent identities and do not exhibit excessive intercorrelations with other constructs. The establishment of discriminant validity in SMART-PLS involves the utilization of three distinct methodologies.

Fornell and Larcker Criterion:

As per the criterion proposed by Fornell and Larcker, the presence of discriminant validity can be confirmed if the square root of the variance (Sq. of a particular construct's AVE root) is found to be higher than its correlation with all other constructs.

Cross Loadings:

As per the concept of cross loadings, it is expected that a particular item would exhibit higher loadings on its corresponding parent construct in comparison to other constructs that are being examined in the research. The existence of discriminant validity issues can be inferred if an item demonstrates good loading onto a construct other than its own parent construct. When a loading is less than 0.10, it suggests that the item is cross-loading onto another construct. This can potentially compromise the discriminant validity of the measurement.

Heterotrait-Monotrait (HTMT) Ratio:

According to Henseler et al. (2015), in a path model that comprises conceptually similar constructs such as affective satisfaction, cognitive satisfaction, and loyalty, a threshold value of 0.90 is recommended. If the HTMT value exceeds 0.90, it indicates a deficiency in discriminant validity. In cases where the constructs of the path model exhibit greater conceptual differentiation, it is advisable for researchers to consider a threshold of 0.85 for the heterotrait-monotrait ratio of correlations (HTMT) (Henseler et al., 2015).

3.3.2 Structural Assessment

The assessment involved the following inspections (Rahman, I.A. et.al 2022);

1. Path relationship strength
2. Coefficient of determination
3. Predictive relevance of the model
4. Goodness-of-fit (GoF)
5. Hypotheses of the paths

Path Relationship Strength

As per the findings of Hair et al. (2019), path coefficients are gauged using a beta value, which signifies the potency of the path or association between exogenous and endogenous constructs, with values ranging from -1 to +1 (although values may fall outside of this range, they are generally within these bounds). Path coefficients with values near +1 indicate robust positive associations, while negative values indicate the opposite, and these are typically statistically significant. The magnitude of the estimated coefficients tends towards 0 as the strength of the relationships increases.

Coefficient of Determination

The R², or coefficient of determination, is a measure of the impact that exogenous variables have on endogenous model variables when considered together. The coefficient of determination (R²) is a statistical measure that varies between 0 and 1, with values approaching 1 signifying a higher degree of precision in predicting outcomes. The R² threshold value suggested by Cohen (1988) was utilized in this investigation. This value deems an R² score of 0.26 significant, 0.13 moderate, and 0.02 weak. The R² coefficient of determination for the present model was obtained by utilizing the PLS algorithm function within the SmartPLS software. The resulting value of 0.720 indicates a significant impact.

Predictive Relevance of The Model

The determination of predictive significance involves the computation of the (q²) index, which relies on Q² values that measure the variations between predicted and missing data points (Chin, 1998; Tenenhaus et al., 2005). The generation of predictive relevance (q²) values can be achieved through the implementation of the blindfolding iteration procedure, as suggested by Cohen (1988). This involves using the equation provided below:

$$q^2 = \frac{Q_{included}^2 - Q_{excluded}^2}{1 - Q_{included}^2}$$

where;

- q² = predictive relevance
- Q²_{included} = value of the endogenous latent variable where all the exogenous construct variables are included in the model
- Q²_{excluded} = a selected exogenous construct is excluded from the model

The Q² value is calculated by utilizing the Q²_{excluded} value, which is generated by eliminating each construct during the blindfolding procedure. The aforementioned iterative process was subsequently replicated for every exogenous structure until the task was finished. Cohen's (1988) guideline suggests that a q² value between 0.02 and 0.15 indicates a small predictive relevance for the exogenous construct, while a q² value between 0.15 and 0.35 indicates a medium predictive relevance. A q² value greater than 0.35 indicates a large predictive relevance for the respective exogenous construct.

Goodness-of-Fit (GoF)

The GoF index is employed to assess the overall soundness of a model. According to Hair, Ringle, and Sarstedt (2011), the model's geometric mean is derived from the average communality (AVE) and average determination coefficients (R^2). The goodness-of-fit (GoF) metric of the model ought to be confined to the interval of 0 to 1. According to several studies (Wetzels et al., 2009; Akter et al., 2011; Hauashdh et al., 2022), the model's validating power can be categorized as small, medium, or high/large based on the value of a certain parameter. Specifically, if the value falls between 0.1 and 0.25, the model is deemed to have low validating power. If the value falls between 0.25 and 0.36, the model is considered to have medium validating power. Finally, if the value is equal to or greater than 0.36, the model is classified as having high or large validating power. Consequently, the GoF index of a model can be manually computed using the following formula:

$$GoF = \sqrt{AVE \times \bar{R}^2}$$

where;

- GoF = goodness-of-fit
- AVE = average communality
- R^2 = coefficients of determination

CHAPTER 4

RESULTS DISCUSSION

4.1 Overview

The aim of this study is to find how knowledge management of designer's impact project performance (design package) in the construction industry. To ensure an adequate response rate from the sample for this research, the questionnaire was distributed in October 2023 to designated personnel in 53 grade 1 and grade 2 Design office/consultancy located within the Eastern province of Saudi Arabia. The designated personnel were asked to direct the questionnaire to the most appropriate person in the organization to complete and return. Some designated personnel received more than one questionnaire with a request to direct them to more qualified professionals. A total of 97 questionnaires were shared with the designated personnel.

The designated personnel were asked to share the questionnaire with experts in their organizations. In order to increase participation, a regular follow up with the designated personnels through emails and WhatsApp reminder messages was made. A total of 80 filled questionnaires were received, which means that more than one response was received from some designers, resulting in an 82.5% response rate. After screening the received completed questionnaires for completeness and quality of responses, six questionnaires were deemed incomplete, and were eliminated, resulting in a total of 74 valid responses from unique respondents. The data was then validated and analyzed using PLS software. Further details about the validation process and research findings are presented in subsequent sections.

4.2 Characteristics of Responders

Table 4.1 displays the general characteristics of the participants in this study, providing information on their demographics, frequencies, and percentages. The table is divided into several dimensions, including gender, age, educational level, job title, department, experience, company field, average project size, and average project duration. Each dimension has multiple categories along with the number of participants listed in each category. A comprehensive overview of the composition of the participant pool is presented, including the distribution of data in frequencies and percentages across various demographic dimensions.

Gender: The gender distribution within the study reveals that a significant majority of participants were male, constituting 80% (59/74) of the total sample, whereas female participants represented a notably smaller proportion, comprising only 20% (15/74) of the sample. This disparity highlights a gender imbalance within the study population.

Age: Participants' ages are categorized into four distinct groups. The data demonstrates that the highest percentage of respondents, 50% (37/74) of the total sample, falls within the age bracket of 30 to less than 40 years. This age group represents a substantial portion of the participants and indicates that the study predominantly engaged with individuals in the early to mid-career stage.

Educational Level: The educational background of participants exhibits considerable variation, with responses distributed among five distinct categories. A substantial majority of participants, 82% (61/74), reported holding a Bachelor of Science (BSc) degree. This finding suggests a strong prevalence of undergraduate education among the study's sample.

Position: The breakdown of participants' job titles underscores a diverse range of roles within the field of construction and project management. Notably, 46% of respondents identified themselves as Designer/Architect, making this the most common job title. Project Design Lead, Project Manager, and Owner accounted for 38%, 11%, and 4% of the total

sample, respectively. This diversity in job titles reflects the multidisciplinary nature of the construction industry.

Department: Within the context of departmental affiliations, the majority of participants, constituting 86% of the sample, were associated with the Architecture department. This finding underscores the prevalence of design-related roles and responsibilities among the study's participants, reflecting the domain's importance in the construction industry.

Experience Level: Participants' levels of professional experience encompass four categories. The data indicates that 35% of respondents possessed 10 years or more of experience, signifying a cohort of seasoned professionals. Additionally, 34% of participants reported having between 5 and less than 10 years of experience, highlighting a significant proportion of mid-career professionals within the study.

Company Field: The participants in the study represented a diverse spectrum of industry sectors, with 42% of them engaged in the Residential Construction field, while 31% of them engaged in the building construction field. This diversity in company fields suggests that the study's findings may have broader implications and relevance across various industries.

Average Project Size: The survey explored participants' involvement in projects of varying sizes, with responses falling into five discrete categories. Notably, 38% of participants were associated with projects ranging from 150 million to less than 250 million SAR. This variation in project size underscores the diverse scope of projects managed by participants.

Employer: The participants' professional affiliations within the construction industry encompass consulting offices (58%), contractors (6%), and other roles (10%). This diverse distribution adds depth to the demographic analysis of the study.

The findings from this comprehensive demographic analysis collectively affirm the credibility and reliability of the dataset. Notably, to ensure data completeness and maintain data quality, six questionnaires were excluded from the analysis due to their incompleteness. This detailed analysis provides a comprehensive understanding of the participant demographics, forming a critical foundation for subsequent discussions in the research report.

Table 4-1: Characteristics of Respondents

Dimension	Variable	Frequency	Percentage%
Gender	Male	59	80%
	Female	15	20%
	Total	74	100%
Age	20 to less than 30	24	32%
	30 to less than 40	37	50%
	40 to less than 50	12	16%
	50 and older	1	1%
	Total	74	100%
Education	Highschool or diploma	0	0%
	BSc	61	82%
	MSc	11	15%
	PHD	2	3%
	Other	0	0%
	Total	74	100%
Experience Level	Less than 5 years	23	31%
	5 to less than 10 years	25	34%
	10 to less than 15 years	23	31%
	15 years or more	3	4%
	Total	74	100%
Department	Architecture	64	86%
	Engineering	5	7%
	Project Management	4	5%
	Other	1	1%

Employer	Total	74	100%
	Consulting Office	58	78%
	Contractor	6	8%
	Other	10	14%
Position	Total	74	100%
	Architect/Designer	34	46%
	Design Lead	28	38%
	Project Manager	8	11%
	Design Engineer	1	1%
	Owner	3	4%
Company Field	Total	74	100%
	Residential Construction	51	42%
	Building Construction	37	31%
	Design Office	24	20%
	Other	9	7%
Average Project Size	Total	121	100%
	Less than 50 million	18	24%
	50-150 million	10	14%
	150-250 million	28	38%
	More than 250 million	18	24%
Total		74	100%

4.3 Model Assessment and Validation

This section is dedicated to explaining the validation of the developed model using Smart PLS software that revolutionized latent variable modeling. It combines advanced approaches (PLS-POS, IPMA, sophisticated bootstrapping processes) with an intuitive graphical user interface. Figure 4.1 represents the conceptual framework of the developed model constructed using Smart PLS software for validation purposes.

Each of these factors is referred to as a "Latent Variable" in the Smart PLS program since it is measured by a series of questions that are reflective of it rather than by itself. For instance, the questionnaire in Appendix A contains questions that show how each latent variable of Knowledge Management Factors is measured. All participants responded to these questions with a number between 1 and 5, which corresponds to the statements 1 "strongly disagree", 2 "disagree", 3 "neutral", 4 "agree", 5 "strongly agree". The term "Measured Variable" refers to each item from the set of surveys that together form the latent variable.

The proposed conceptual framework will investigate the relationship between a group of measurable variables (Questions), which are represented in the framework as an arrow and are referred in Smart PLS as "Loading". Overall, to have a valid and dependable framework, we must identify the convergent and discriminate validity for the measurement model, as suggested by Hair (2012), the programmer of the Smart PLS. The structural model, mediation role and moderation role—all of which are discussed in more detail in the next subsections are then evaluated. The titles and assessments serve as a road map to the subsequent sections, which provide further theoretical details on the validation process.

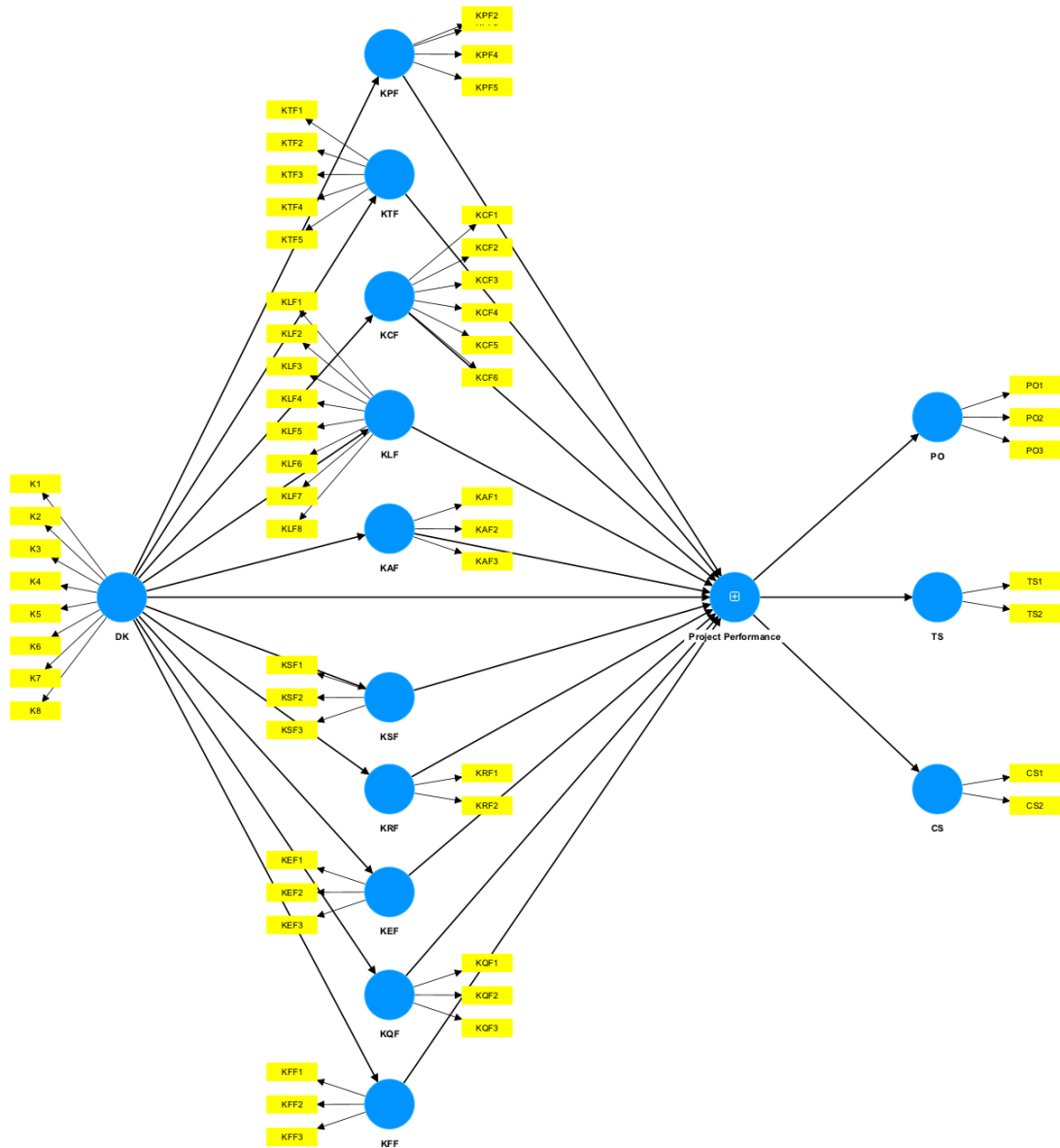


Figure 4.1: Framework Conceptual Framework including Mediators and its Variables]

4.3.1 Assessment of Measurement Model

As can be seen from Figure 4.1, the evaluation of the measurement model is conducted in two phases. First, “Convergent Validity” reflects how close the provided questions are with each other. Second, “Discriminate Validity” measures how far the proposed questions are from each other. Before diving deep into the aforementioned terms, it is important to understand the definition of validity and reliability. For simplicity, it is assumed that five data are collected from the questions. These data are shown as bold dot (.) on Figure 4.2 and their average represented as cross (x). If the cross (average value of the questions) is located at the center of the bull's eye as shown in the top right of Figure 4.2, the used questions are called valid. Otherwise, it can be implied that the questions cannot be used to assess the target variables. To further elaborate, imagine measuring someone's height using a scale of weight, which is definitely not a proper measurement method.

The Smart PLS program automatically calculates the average value of each question by averaging the responses to the questions that have been inserted into the program. The target center value is a criterion provided by the PLS developer that is based on a large body of statistical research. It's important to mention that if a non-valid result is produced where the average does not satisfy the criteria specified in the test (target center), simply some questions are deleted until the targeted average is achieved. If the latter procedure did not shift the data toward the targeted average, then it can be concluded that the questions are invalid.

Reliability, on the other hand, isn't concerned with hitting the bull's eye, rather with how near the measurements (the data acquired via questions) are to the mean value (cross). As depicted by the lower bottom of Figure 4.3, the upper and lower limits are not in the perfect spot, indicating that they are invalid. However, the data is still considered reliable because it is distributed around the average in the upper left corner of Figure 4.3. By observing how far off the data is from the target, its invalidity may readily be ascertained. Assessing reliability is the first stage in checking validity. If the measurements are unreliable, the result cannot be trusted.

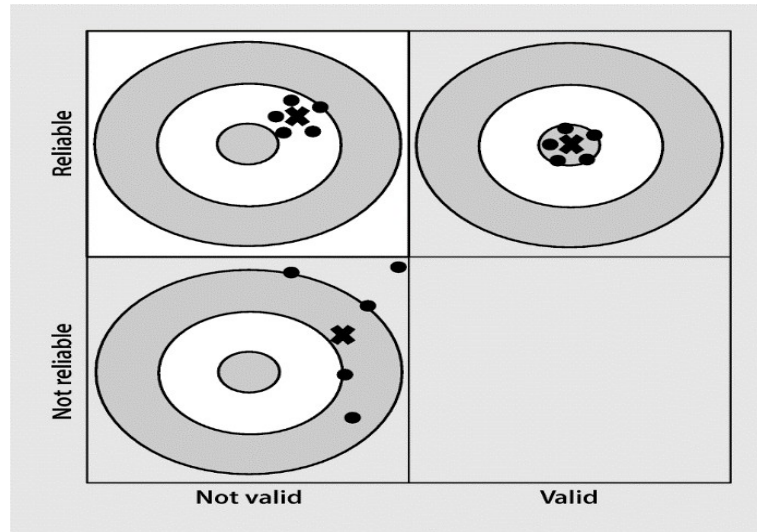


Figure 4.2: Reliability and Validity Explanation (Mooi & Sarstedt, (2011))

- **Convergent Validity**

According to Hair et al. (2011), the convergent validity is defined as “the extent to which a measure correlates positively with alternative measures of the same latent variable”. PLS software offers four different methods for measuring convergent validity; Individual item reliability, Cronbach alpha, Average variance extracted, and Composite reliability. These are explained as follows:

Cronbach Alpha: In 1951, Lee Cronbach developed Cronbach's alpha coefficient which evaluates the internal consistency or dependability of a group of survey questions. This statistic is utilized to find out if a group of items consistently evaluate the same characteristic. Cronbach's alpha measures the level of agreement on a standardized 0 to 1 scale. Higher numbers indicate higher level of agreement among the items. High Cronbach's alpha values propose that the responses are consistent across a group of questions. For example, when respondents respond highly to one question, they are likely to respond highly to the other questions also. This consistency indicates that the measurements are accurate, and the items may evaluate the similar characteristics.

In contrast, low scores suggest that the set of items does not measure the same construct in a reliable manner. High responses to a single question are not indicative of the participants' assessments on the remaining items. Due to the unreliability of the measurements, it is highly improbable that the questions measure the same characteristic. Cronbach's alpha equation, presented below, is used to measure three main statistics namely; precision lower coefficient, spilt-half coefficients mean, and first factor upper bound concentration.

$$\alpha = \frac{n}{n-1} \left(1 - \frac{\sum V_i}{V_t} \right)$$

Where:

n: questions number

V_i : individual measure variance

V_t : total score variance

The criteria to evaluate the value of (α) is provided in Table 4.2

“Cronbach’s Alpha	Internal Consistency
Criteria	
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable”

Table 4-2: Criteria to Evaluate the Value of (α)

Table 4.3 and Figure 4.3 presents the Cronbach's alpha coefficients for variety of constructs in the study. Cronbach's alpha measures internal consistency reliability, indicating how well the items measuring a construct are interrelated. The commonly accepted threshold for an acceptable level of Cronbach's alpha is 0.70 or above.

In the context of this research, the assessment of internal consistency reliability through Cronbach's alpha values underscores the robustness of the constructs examined. The constructs can be systematically classified into three discernible groups based on their reliability coefficients. The first classification encompasses constructs that exhibit a notably high level of internal consistency reliability, as indicated by Cronbach's alpha values surpassing the 0.85 threshold. This includes KAF (Knowledge Acquisition Factor) with an impressive Cronbach's alpha of 0.935, emphasizing the reliability of this construct in capturing knowledge acquisition tendencies. Additionally, constructs like KCF (Knowledge Culture Factor) at 0.856, KFF (Knowledge Financing Factor) at 0.891, KLF (Knowledge

Leadership Factor) at 0.913, KSF (Knowledge Sharing Factor) at 0.8, and KTF (Knowledge Technology Factor) at 0.872 showcase robust internal consistency.

Moving to the second category, constructs within this group exhibit a moderate level of internal consistency reliability, with Cronbach's alpha values ranging between 0.70 and 0.85. Noteworthy constructs in this group include KEF (Knowledge Education Factor) at 0.746, reflecting the construct's satisfactory reliability in assessing the importance of continuous learning and skill development, and KPF (Knowledge Quality Factor) at 0.726, capturing aspects related to the accuracy, relevance, and usability of knowledge. Lastly, the third category comprises two construct, CS (Customer Satisfaction) and KRF (Knowledge Retention Factor), with Cronbach's alpha values less than 0.70.

The overall consensus drawn from the robust Cronbach's alpha values across these constructs significantly enhances the credibility and trustworthiness of the study's findings, affirming the reliability of the measurement instruments employed in capturing the nuances of knowledge-related factors under investigation.

Table 4-3: Values of Cronbach's Alpha (a)

Construct	Cronbach's alpha
CS	0.602
DK	0.895
KAF	0.935
KCF	0.856
KEF	0.746
KFF	0.891
KLF	0.913
KPF	0.726
KQF	0.794
KRF	0.682
KSF	0.884
KTF	0.872
PO	0.799
Project Performance	0.864
TS	0.622



Figure 4.3: Values of Cronbach's Alpha (a)

Composite Reliability

Composite reliability (CR) is very much similar to Cronbach's alpha method of measuring internal variable consistency. Put differently, CR reflects overall reliability of the set measured variable through combining the measured variable covariance and variance and divide by overall composite sum of the measured variable, in addition to error term variance. The CR factor has a range of 0 to 1, with a higher value indicating greater validity. When the value is less than 0.6, the measured variable is believed to be unreliable. CR formula is shown below (Bacon et al., 1995).

$$\frac{(\sum_{i=1}^p \lambda_i)^2}{(\sum_{i=1}^p \lambda_i)^2 + \sum_{i=1}^p V(\delta)}$$

Where:

λ_i : ith measured variable completely standard loading

$V(\delta)$: ith measured term error variance

p : measured variable number.

Individual Item Reliability (Factor Loading)

Factor loading (FL) (The value shown on the model arrow) is found in a structure or factor pattern matrix. FL signifies the correlation coefficient between the latent variable and the measured variable. The greater the value, the greater the reliability. If the result falls between 0.4 and 0.7, it is deemed unreliable. Steps outlined in Figure 4.4 shall be followed to determine whether or not to keep the question (measured variable) in the model.

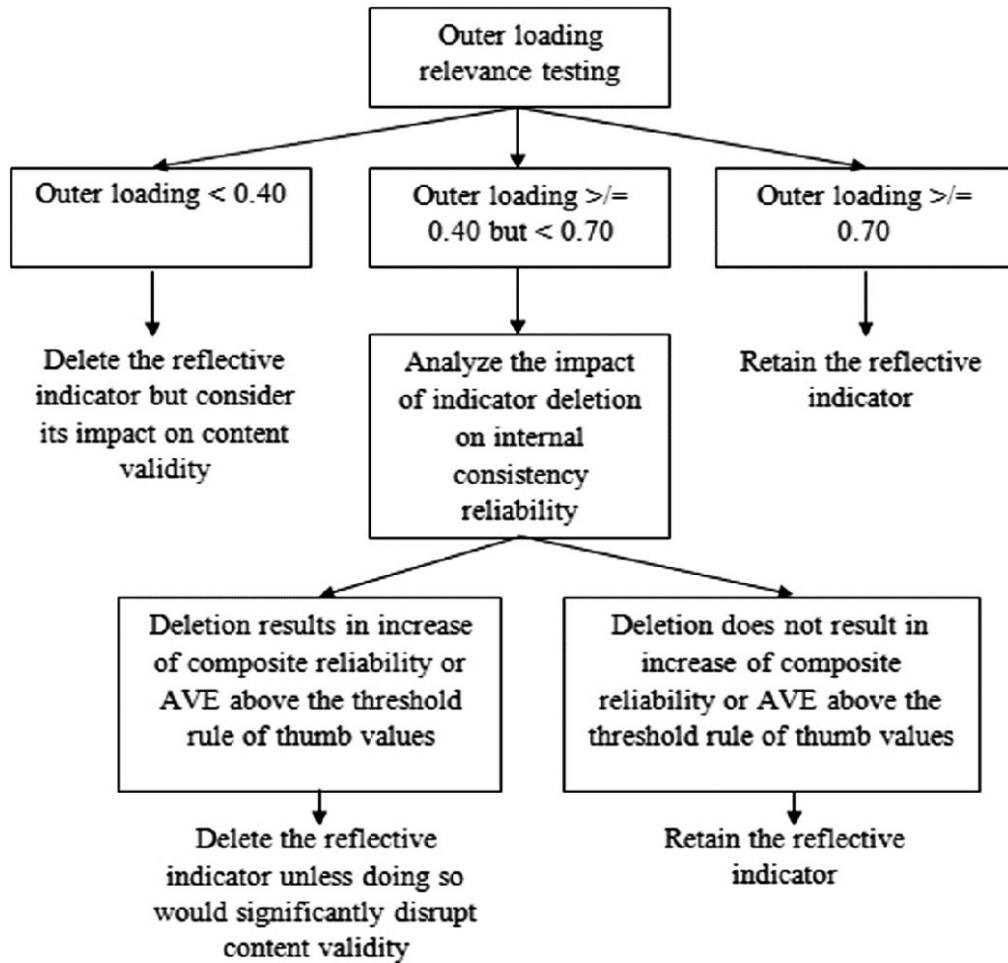


Figure 4.4: Criteria Whether or not to Keep the Question (Measured Variable) in the Model]

In PLS software, two types of composite reliability, rho_a and rho_c are used to evaluate internal consistency or credibility of the survey items, that measure a construct or a latent variable. Table 4.4 and Figures 4.5 & 4.6 show the composite reliability values for the constructs measured by the survey. The table reports two different measures of composite validity, rho_a and rho_c, for each construct. The first measure, rho_a, is the traditional measure of composite reliability in PLS- SEM, which is based on the average variance extracted (AVE) of the construct and the factor loadings of its items. The second measure, rho_c, is an alternative measure of composite reliability that considers the cross-loadings of the items on other constructs.

The table 4.4 shows that the constructs have relatively high levels of composite reliability, with most values above 0.8 for both rho_a and rho_c. This indicates that the survey items measuring each construct are internally consistent and reliable. However, some constructs, such as AQ and IQ, have lower levels of composite reliability, particularly for rho_a. This suggests that the items measuring these constructs may need further refinement or revision to improve their reliability. On the other hand, constructs such as PP and MSQ have very high levels of composite reliability, indicating that the survey items measuring these constructs are highly reliable.

Table 4-4: Composite Reliability Values

Construct	Composite reliability (rho_a)	Composite reliability (rho_c)
CS	0.611	0.833
DK	0.919	0.917
KAF	0.938	0.958
KCF	0.862	0.893
KEF	0.757	0.856
KFF	0.891	0.933
KLF	0.919	0.929
KPF	0.769	0.824
KQF	0.813	0.88
KRF	0.711	0.861
KSF	0.889	0.929
KTF	0.875	0.908
PO	0.8	0.883
Project Performance	0.866	0.896
TS	0.634	0.84

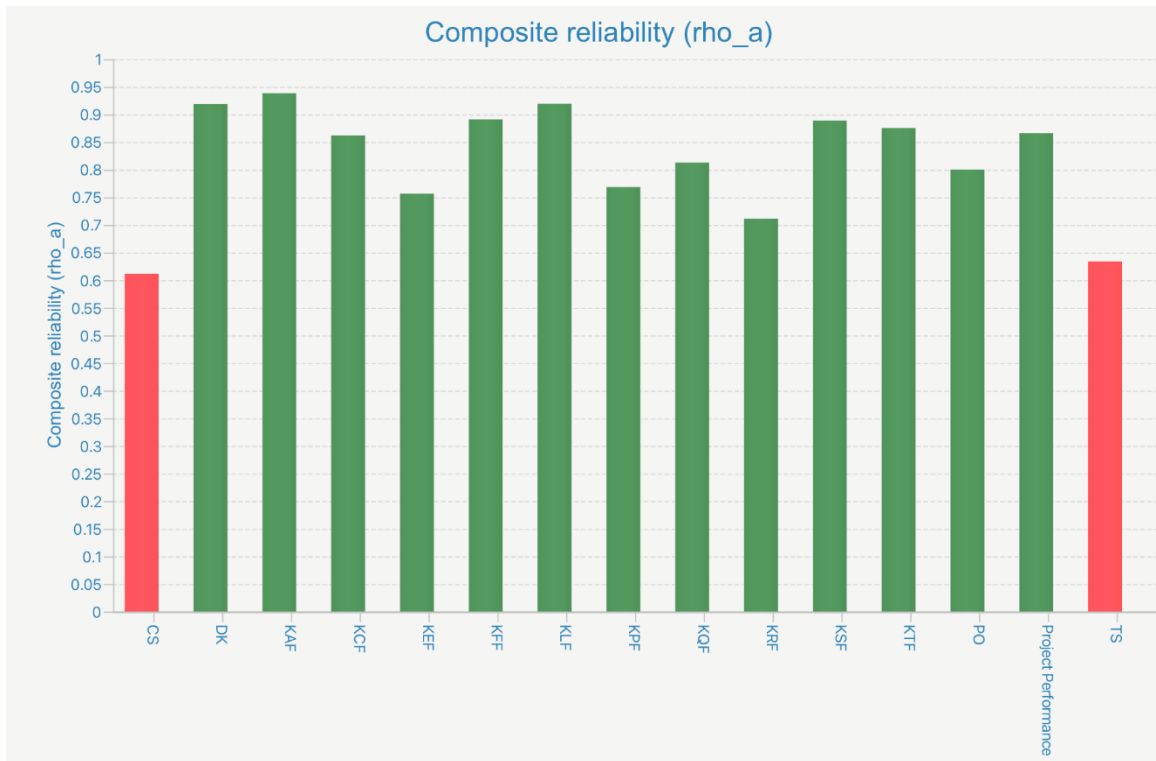


Figure 4.5: Composite Reliability ρ_a

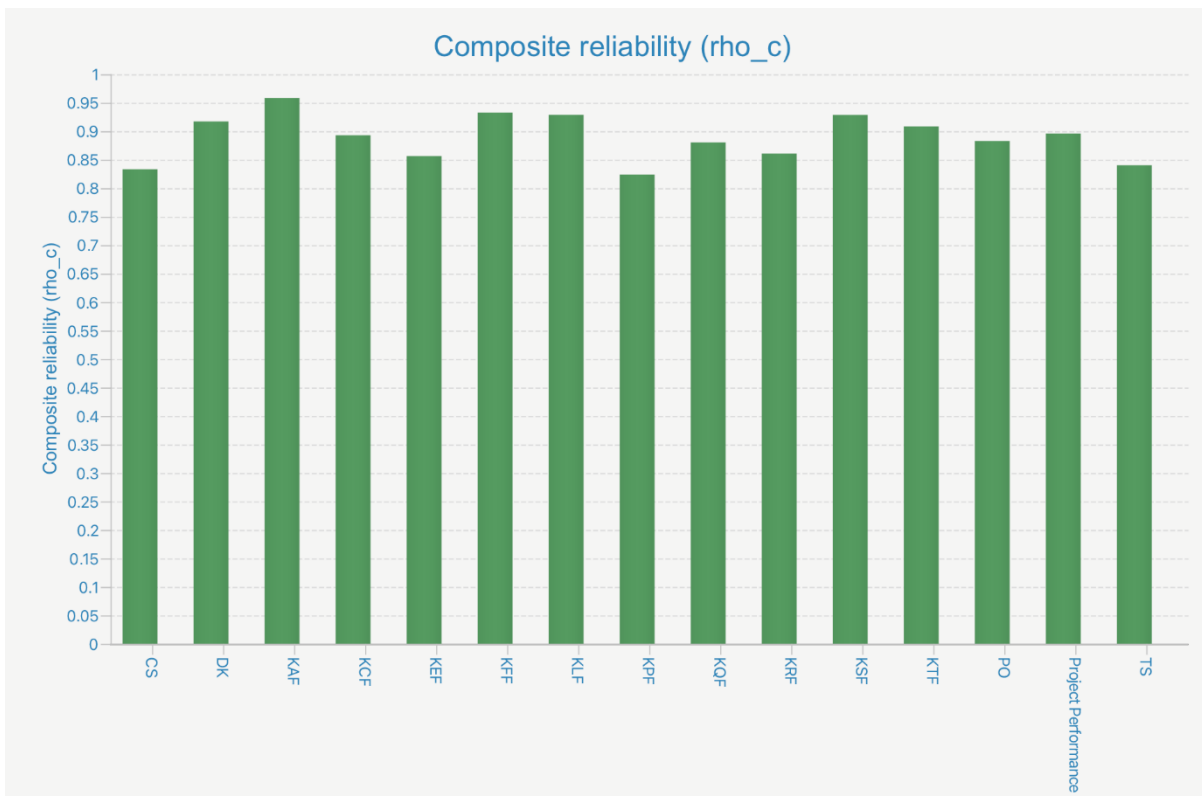


Figure 4.6: Composite Reliability ρ_c

Average Variance Extracted (AVE)

Mean values of square loading divided by the number of the measured variable can be used to express the “Average Variance Extracted” (AVE), which calculates the level of variance expressed by latent variable against the level of measurement error. When the value is less than 0.5, the measured variable is considered to be unreliable. AVE formula is presented below:

$$AVE = \frac{\sum_{i=1}^k \lambda_i^2}{\sum_{i=1}^k \lambda_i^2 + \sum_{i=1}^p Var(e_i)}$$

Where:

K: latent variables indicator number

λ : factor loading

e_i : kth indicator of error variance

Based on the results provided by PLS software (Table 4.5 & Figure 4.7), the AVE values for all the constructs are above the acceptable threshold of 0.5, indicating good convergent validity. The highest AVE value is for KAF (0.885), followed by KFF (0.822), suggests that these constructs have the highest amount of variance explained by their respective indicators.

The constructs with the lowest AVE values are PP (0.553) and KCF (0.582), which still meet the minimum threshold of 0.5 but are on the lower end, construct KPF (0.490) was below the threshold of 0.5 as shown in figure 4.6 but to improve the data it was modified by deleting one of the low performing latent variables taking it to a value of (0.608). It is important to note that constructs with low AVE values may indicate a lack of convergent validity, and researchers should further examine the indicators and consider removing them if they do not adequately measure the latent construct.

Overall, the high AVE values for most of the constructs in the table suggest that the indicators used to measure the constructs are reliable and valid, which supports the findings of the study. Table 4.6 summarize the PLS Convergent Validity Results which shows that all values for alpha, CR and AVE compared to the minimum threshold.

Table 4-5: Average Variance Extracted (AVE) Values

Construct	Average variance extracted (AVE)	Average variance extracted (AVE) modified
CS	0.714	0.714
DK	0.585	0.585
KAF	0.885	0.885
KCF	0.582	0.582
KEF	0.666	0.666
KFF	0.822	0.822
KLF	0.620	0.620
KPF	0.490	0.608
KQF	0.712	0.712
KRF	0.756	0.756
KSF	0.813	0.813
KTF	0.667	0.667
PO	0.716	0.716
Project Performance	0.553	0.553
TS	0.725	0.725

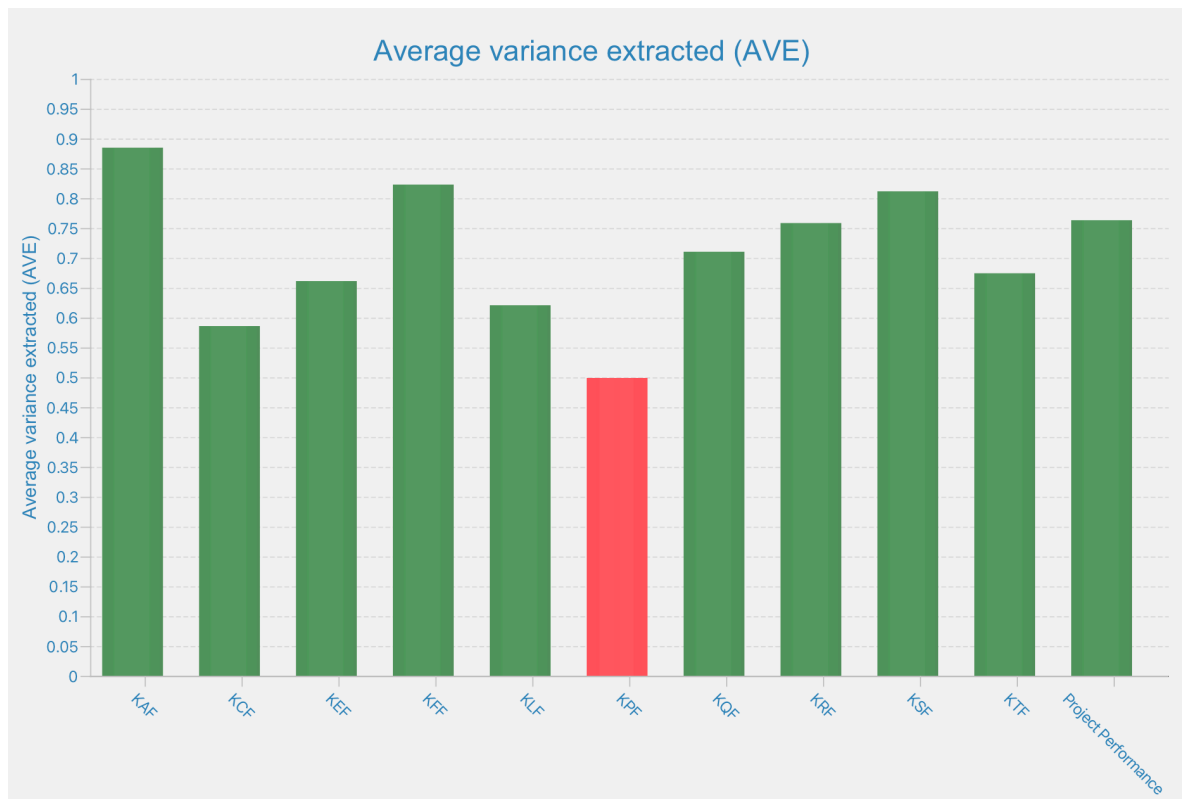


Figure 4.7: Average Variance Extracted (AVE)

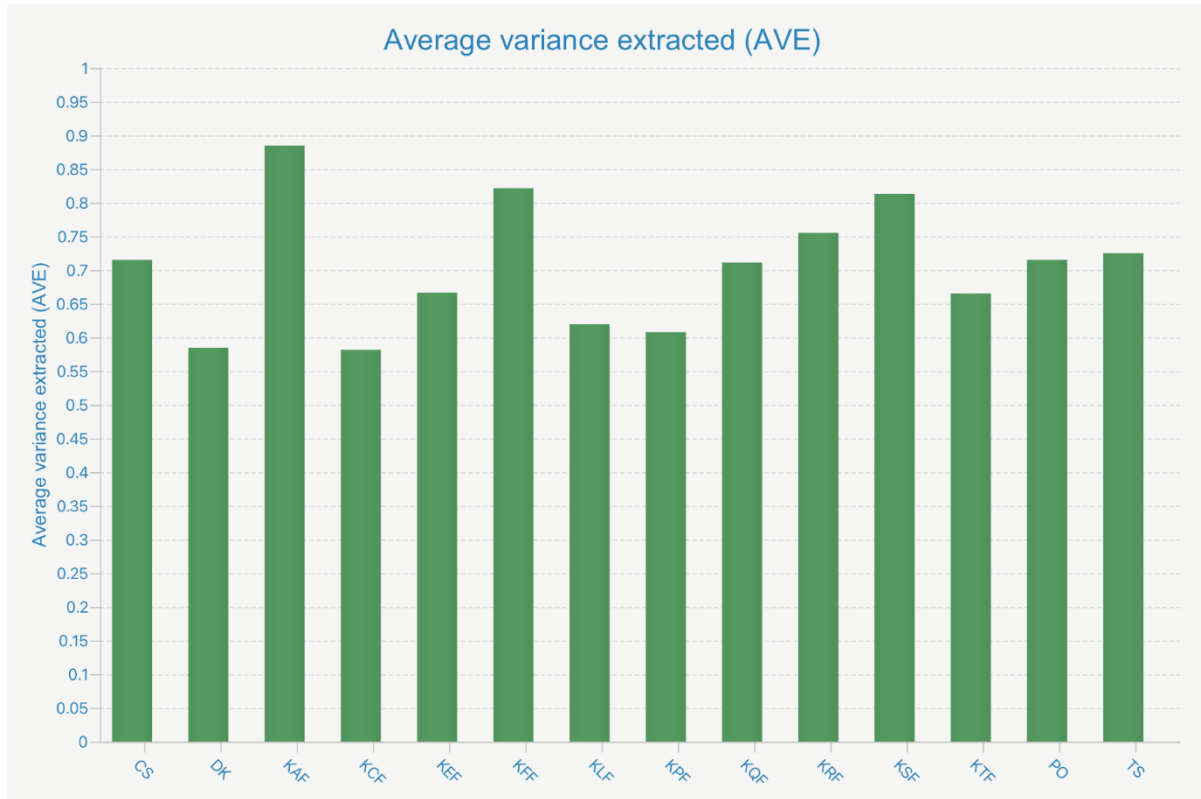


Figure 4.8: Average Variance Extracted (AVE) after Modification

Table 4-6: Initial Convergent Reliability factors

Construct (Latent Variable)	Item (Indicator)	Loading	Alpha (α) (>0.7)	CR (>0.7)	AVE (>0.5)
DK	DK1	0.724	0.895	0.919	0.585
	DK2	0.716			
	DK3	0.765			
	DK4	0.899			
	DK5	0.673			
	DK6	0.803			
	DK7	0.583			
	DK8	0.900			
KPF	KPF1	0.361	0.726	0.769	0.608
	KPF2	0.730			
	KPF3	0.795			
	KPF4	0.817			
	KPF5	0.715			

KTF	KTF1	0.649	0.872	0.875	0.667
	KTF2	0.874			
	KTF3	0.777			
	KTF4	0.850			
	KTF5	0.909			
KCF	KCF1	0.729	0.856	0.862	0.582
	KCF2	0.806			
	KCF3	0.708			
	KCF4	0.735			
	KCF5	0.830			
	KCF6	0.763			
KLF	KLF1	0.752	0.913	0.919	0.620
	KLF2	0.792			
	KLF3	0.796			
	KLF4	0.714			
	KLF5	0.790			
	KLF6	0.787			
	KLF7	0.827			
	KLF8	0.834			
KAF	KAF1	0.94	0.935	0.938	0.885
	KAF2	0.955			
	KAF3	0.926			
KSF	KSF1	0.936	0.884	0.889	0.813
	KSF2	0.838			
	KSF3	0.927			
KRF	KRF1	0.834	0.682	0.711	0.756
	KRF2	0.904			
KEF	KEF1	0.826	0.746	0.891	0.666
	KEF2	0.882			
	KEF3	0.735			
KQF	KQF1	0.883	0.794	0.813	0.712
	KQF2	0.741			
	KQF3	0.898			
KFF	KFF1	0.855	0.891	0.891	0.822
	KFF2	0.929			
	KFF3	0.934			
PO	PO1	0.875	0.799	0.800	0.716

	PO2	0.881			
	PO3	0.788			
TS	TS1	0.824	0.622	0.634	0.725
	TS2	0.878			
CS	CS1	0.871	0.602	0.611	0.714
	CS2	0.819			

The initial analysis identified some unsatisfactory results, such as the AVE value for KPF being below the minimum threshold of 0.5 at 0.490. To enhance the analysis, a meticulous examination of latent variables for each mediator was conducted. The subsequent step involved eliminating those with low loading factors, exemplified by the removal of latent variable KPF1 with a loading of 0.361. This strategic adjustment was consistently applied to each mediator. The improved analysis, detailed in Table 4.7, revealed notable enhancements across all parameters. For instance, KPS's AVE increased to 0.608, surpassing the 0.5 threshold, and DK exhibited improvement, with AVE rising from 0.585 to 0.644. Additionally, there was an enhancement in CR from 0.895 to 0.936, indicating that neglecting low relationship latent variables positively influenced overall relationship significance.

The updated analysis of the latent variable model underscores improved reliability and validity measures for key indicators. Specifically, in the DK construct, DK1 maintained a robust loading of 0.724, significantly contributing to the overall reliability. The alpha coefficient for DK increased to 0.903, exceeding the recommended threshold of 0.7, indicating heightened internal consistency. Moreover, there were improvements in composite reliability (CR) and average variance extracted (AVE), reaching 0.936 and 0.644, respectively, further affirming the construct's robustness. In the KPF construct, KPF2 displayed a loading of 0.730, contributing to the overall reliability, with alpha, CR, and AVE meeting acceptable thresholds. Similar enhancements were observed in the KTF and KCF constructs, where key indicators like KTF2 and KCF1 demonstrated increased loadings and improved reliability measures. The KLF construct benefited from stronger indicators, with KLF1 maintaining a loading of 0.752, contributing to higher alpha (0.906) and CR (0.925). In the KEF construct, KEF1 exhibited a substantial loading of 0.826, resulting in improved reliability (alpha = 0.796) and convergent validity (AVE = 0.830).

Overall, the updated analysis suggests increased robustness and reliability of the latent variable model, offering researchers a more precise representation of the underlying constructs. In summary, the corrected AVE values for most constructs in Table 4.7 indicate that the indicators used to measure the constructs are reliable and valid, supporting the study's findings. Table 4.7 summarizes the PLS Convergent Validity Results, demonstrating that all values for alpha, CR, and AVE meet the minimum threshold.

Table 4-7: Improvised Convergent Reliability factors

Construct (Latent Variable)	Item (Indicator)	Loading	Alpha (α) (>0.7)	CR (>0.7)	AVE (>0.5)
DK	DK1	0.724	0.903	0.936	0.644
	DK2	0.716			
	DK3	0.765			
	DK4	0.899			
	DK5	0.673			
	DK6	0.803			
	DK8	0.900			
KPF	KPF2	0.730	0.783	0.860	0.607
	KPF3	0.795			
	KPF4	0.817			
	KPF5	0.715			
KTF	KTF2	0.874	0.912	0.938	0.792
	KTF3	0.777			
	KTF4	0.850			
	KTF5	0.909			
KCF	KCF1	0.729	0.851	0.893	0.628
	KCF2	0.806			
	KCF4	0.735			
	KCF5	0.830			
	KCF6	0.763			
KLF	KLF1	0.752	0.906	0.925	0.639
	KLF2	0.792			
	KLF3	0.796			
	KLF5	0.790			

	KLF6	0.787			
	KLF7	0.827			
	KLF8	0.834			
KAF	KAF1	0.94	0.935	0.938	0.885
	KAF2	0.955			
	KAF3	0.926			
KSF	KSF1	0.936	0.884	0.889	0.813
	KSF2	0.838			
	KSF3	0.927			
KRF	KRF1	0.834	0.682	0.711	0.756
	KRF2	0.904			
KEF	KEF1	0.826	0.796	0.907	0.830
	KEF2	0.882			
KQF	KQF1	0.883	0.794	0.813	0.712
	KQF2	0.741			
	KQF3	0.898			
KFF	KFF1	0.855	0.891	0.891	0.822
	KFF2	0.929			
	KFF3	0.934			
PO	PO1	0.875	0.799	0.800	0.716
	PO2	0.881			
	PO3	0.788			
TS	TS1	0.824	0.622	0.634	0.725
	TS2	0.878			
CS	CS1	0.871	0.602	0.611	0.714
	CS2	0.819			

- **Discriminate Validity**

Discriminant validity is a statistical concept used in research to assess whether a measurement instrument (such as a survey or test) is distinct from other constructs it is not supposed to measure. It ensures that the tool accurately captures the unique characteristics of the specific concept it intends to measure, demonstrating that it is not conflated or highly correlated with unrelated factors. In essence, discriminant validity confirms that the measurement instrument is capable of distinguishing between different constructs, providing clear evidence of its specificity and precision.

Fornell and Larcker Criterion

When convergent validity was evaluated using AVE, it was discovered that it could also capture discriminating validity by using the square root of the value, which was later called the Fornell and Larcker Criterion. This criteria functions as a matrix, with the upper limit of the matrix representing each variable which must be greater than other variables in order to be valid. In other words, when the value of a latent variable itself is greater than the values of all other variables by themselves, it indicates that the variable is unique and qualifies to be included in the model.

Table 4.8 reflects the results of the Fornell and Larcker Criterion analysis, which is used to assess the discriminant validity of the constructs in a model. The diagonal values in the table represent the square root of the Average Variance Extracted (AVE) for each construct, while the off-diagonal values signify the correlations between constructs.

Table 4-8: Fornell and Larcker Criterion analysis

	CS	DK	KAF	KCF	KEF	KFF	KLF	KPF	KQF	KRF	KSF	KTF	PO	TS
CS	0.846													
DK	0.290	0.803												
KAF	0.556	0.214	0.941											
KCF	0.667	0.352	0.771	0.892										
KEF	0.546	0.506	0.413	0.568	0.911									
KFF	0.354	0.297	0.506	0.549	0.417	0.906								
KLF	0.563	0.388	0.543	0.744	0.718	0.627	0.800							
KPF	0.556	0.333	0.683	0.841	0.559	0.533	0.735	0.879						
KQF	0.588	0.537	0.651	0.725	0.710	0.521	0.762	0.641	0.843					
KRF	0.602	0.504	0.633	0.809	0.748	0.579	0.690	0.693	0.750	0.868				
KSF	0.648	0.347	0.556	0.675	0.657	0.490	0.743	0.684	0.649	0.647	0.902			
KTF	0.434	0.157	0.677	0.776	0.437	0.566	0.701	0.797	0.528	0.559	0.708	0.890		
PO	0.634	0.202	0.516	0.619	0.415	0.573	0.678	0.624	0.593	0.559	0.579	0.550	0.846	
TS	0.611	0.354	0.518	0.625	0.559	0.564	0.755	0.571	0.667	0.545	0.473	0.478	0.683	0.852

AVE represents the extent of variance in each construct that is explained by its indicators, and it is used as an indicator of convergent validity. The Fornell and Larcker Criterion proposes that the AVE for each construct should be higher than its squared correlations with other constructs in the model to demonstrate discriminant validity. Based on the table, all constructs have AVE values greater than their squared correlations along with other constructs, indicating that the constructs have discriminant validity. Additionally, the AVE values for all constructs are greater than 0.5 which indicates good convergent validity. These results are suggestive of the constructs in the model (i.e., Knowledge Management and project manager performance) to be distinct from each other and have good convergent validity, which supports the use of the model for further analysis.

Cross Loading

Cross-loading, which also focuses on the level of the questions themselves (measured variable), assesses how far the measured variables are from each other. This implies, in a matrix perspective, that the value of a variable with itself must be greater than its value with other variables. Once true, it is considered a valid framework variable. Otherwise, it is impractical to have two phenomena and variables that describe the same attribute. In such a case, it is preferable to use the phenomenon and variable with the highest and best value. Notably, if the value of the comparison satisfies the condition of the highest value with itself and has other values that show a close number to itself, that means they have a high degree of correlation. It is most likely that researchers have already studied and addressed how they are related.

Table 4.10 portrays the results of the cross-loading analysis, which is a technique used in partial least squares (PLS) analysis to evaluate the relationship between latent variables and their indicators. Each row in the table represents an indicator variable, and each column represents a latent variable. The numbers in the cells represent the cross-loading coefficients which indicate the strength of the association amongst the indicator variable and the latent variable. A high cross-loading coefficient shows that the indicator variable is a good measure of the latent variable.

For example, looking at the eight row, we can see that KCF5 has relatively high cross-loading coefficients with all the latent variables. This suggests that KCF5 is a good measure of most of the latent variables being studied. This pattern extends to other indicators, such as KSF1 and KSF2, which consistently exhibit high coefficients across multiple latent variables, emphasizing their broad applicability. The analysis aids researchers in identifying key indicators that robustly represent specific constructs, facilitating the refinement of measurement models. Overall, the cross-loading analysis is useful for evaluating the validity of the indicators being used to measure the latent variables and can help researchers refine their measurement model to improve the accuracy of their results.

Table 4-10: Cross-loading Values

	CS	DK	KAF	KCF	KEF	KFF	KLF	KPF	KQF	KRF	KSF	KTF	PO	Project Performance	TS
CS1	0.856	0.18	0.624	0.565	0.425	0.329	0.401	0.481	0.428	0.462	0.459	0.419	0.609	0.74	0.548
CS1	0.856	0.18	0.624	0.565	0.425	0.329	0.401	0.481	0.428	0.462	0.459	0.419	0.609	0.74	0.548
CS2	0.835	0.325	0.309	0.591	0.645	0.268	0.555	0.456	0.573	0.561	0.645	0.437	0.461	0.695	0.485
CS2	0.835	0.325	0.309	0.591	0.645	0.268	0.555	0.456	0.573	0.561	0.645	0.437	0.461	0.695	0.485
K1	0.109	0.724	0.036	0.151	0.303	0.248	0.199	0.151	0.358	0.268	0.331	0.15	0.13	0.186	0.218
K2	0.22	0.717	0.354	0.283	0.21	0.223	0.291	0.288	0.43	0.263	0.216	0.28	0.174	0.292	0.375
K3	0.221	0.764	-0.035	0.227	0.322	0.146	0.235	0.159	0.354	0.351	0.228	0.157	0.156	0.254	0.241
K4	0.333	0.899	0.197	0.379	0.436	0.259	0.373	0.33	0.528	0.49	0.348	0.301	0.178	0.332	0.331
K5	0.213	0.674	0.385	0.404	0.269	0.214	0.319	0.353	0.321	0.377	0.172	0.319	0.11	0.186	0.19
K6	0.133	0.803	-0.062	0.157	0.27	0.24	0.187	0.091	0.355	0.324	0.176	0.139	0.062	0.168	0.212
K7	0.169	0.583	0.433	0.364	0.188	0.288	0.244	0.468	0.237	0.297	0.153	0.327	0.041	0.119	0.123
K8	0.302	0.9	0.221	0.433	0.53	0.295	0.401	0.362	0.547	0.577	0.384	0.32	0.256	0.364	0.363
KAF1	0.552	0.234	0.94	0.679	0.546	0.558	0.521	0.648	0.626	0.599	0.495	0.641	0.535	0.628	0.561
KAF2	0.487	0.261	0.955	0.634	0.608	0.448	0.507	0.605	0.624	0.594	0.52	0.648	0.466	0.549	0.495
KAF3	0.529	0.292	0.926	0.711	0.576	0.419	0.54	0.681	0.601	0.618	0.567	0.685	0.448	0.521	0.393
KCF1	0.456	0.141	0.766	0.727	0.518	0.448	0.524	0.704	0.527	0.554	0.367	0.666	0.448	0.526	0.473
KCF2	0.59	0.273	0.744	0.804	0.535	0.262	0.539	0.698	0.529	0.621	0.467	0.629	0.467	0.602	0.531
KCF3	0.506	0.378	0.248	0.714	0.663	0.297	0.671	0.508	0.559	0.558	0.555	0.497	0.385	0.519	0.428
KCF4	0.523	0.607	0.319	0.739	0.715	0.365	0.662	0.57	0.705	0.677	0.583	0.58	0.444	0.561	0.47
KCF5	0.492	0.262	0.678	0.827	0.528	0.649	0.699	0.725	0.595	0.686	0.643	0.737	0.592	0.616	0.516
KCF6	0.55	0.135	0.611	0.759	0.412	0.444	0.537	0.627	0.446	0.62	0.549	0.574	0.472	0.556	0.455
KEF1	0.494	0.44	0.353	0.543	0.828	0.288	0.505	0.435	0.616	0.66	0.578	0.459	0.319	0.469	0.392
KEF2	0.501	0.433	0.398	0.622	0.885	0.456	0.747	0.565	0.667	0.691	0.613	0.642	0.431	0.612	0.612
KEF3	0.551	0.176	0.777	0.677	0.729	0.431	0.629	0.568	0.648	0.597	0.573	0.669	0.533	0.619	0.541
KFF1	0.328	0.367	0.273	0.436	0.439	0.857	0.544	0.427	0.464	0.525	0.463	0.443	0.511	0.522	0.499
KFF2	0.287	0.237	0.537	0.517	0.419	0.927	0.604	0.546	0.457	0.531	0.443	0.596	0.537	0.495	0.476
KFF3	0.341	0.25	0.588	0.505	0.451	0.933	0.56	0.488	0.491	0.52	0.42	0.568	0.509	0.536	0.553
KLF1	0.433	0.214	0.515	0.728	0.494	0.475	0.748	0.668	0.609	0.51	0.575	0.674	0.55	0.572	0.52
KLF2	0.432	0.255	0.477	0.701	0.551	0.556	0.788	0.617	0.598	0.58	0.585	0.739	0.52	0.554	0.504
KLF3	0.423	0.388	0.387	0.604	0.71	0.525	0.799	0.523	0.726	0.644	0.533	0.636	0.425	0.567	0.579
KLF4	0.374	0.224	0.453	0.659	0.486	0.435	0.712	0.563	0.434	0.498	0.403	0.62	0.315	0.467	0.527
KLF5	0.456	0.185	0.652	0.618	0.558	0.473	0.788	0.585	0.532	0.486	0.511	0.691	0.552	0.63	0.635

KLF6	0.469	0.318	0.384	0.529	0.602	0.545	0.788	0.577	0.541	0.435	0.673	0.627	0.622	0.677	0.637
KLF7	0.533	0.454	0.351	0.631	0.702	0.523	0.83	0.553	0.656	0.613	0.659	0.571	0.596	0.713	0.688
KLF8	0.396	0.336	0.351	0.639	0.72	0.421	0.837	0.619	0.612	0.59	0.607	0.627	0.529	0.621	0.636
KPF2	0.379	0.334	0.619	0.622	0.391	0.43	0.473	0.739	0.383	0.467	0.401	0.611	0.38	0.431	0.38
KPF3	0.365	0.241	0.524	0.615	0.396	0.433	0.517	0.811	0.465	0.525	0.461	0.63	0.573	0.501	0.376
KPF4	0.436	0.213	0.613	0.675	0.483	0.545	0.667	0.859	0.526	0.533	0.651	0.77	0.563	0.578	0.514
KPF5	0.517	0.394	0.394	0.665	0.677	0.272	0.621	0.7	0.589	0.608	0.582	0.582	0.422	0.555	0.481
KQF1	0.535	0.55	0.499	0.643	0.784	0.489	0.617	0.512	0.887	0.726	0.623	0.525	0.443	0.616	0.588
KQF2	0.515	0.227	0.781	0.659	0.494	0.405	0.561	0.619	0.734	0.556	0.503	0.626	0.576	0.602	0.502
KQF3	0.453	0.519	0.444	0.606	0.686	0.423	0.722	0.521	0.899	0.602	0.516	0.583	0.517	0.612	0.594
KRF1	0.515	0.278	0.77	0.705	0.592	0.562	0.529	0.641	0.537	0.83	0.486	0.619	0.493	0.559	0.473
KRF2	0.536	0.566	0.402	0.722	0.774	0.466	0.661	0.579	0.741	0.907	0.623	0.55	0.487	0.588	0.48
KSF1	0.593	0.345	0.463	0.624	0.738	0.504	0.716	0.573	0.663	0.604	0.937	0.725	0.555	0.635	0.493
KSF2	0.643	0.202	0.651	0.668	0.536	0.453	0.616	0.681	0.534	0.549	0.835	0.71	0.582	0.612	0.398
KSF3	0.52	0.371	0.404	0.604	0.663	0.358	0.637	0.602	0.551	0.591	0.93	0.688	0.43	0.522	0.381
KTF1	0.46	0.55	0.437	0.599	0.74	0.378	0.691	0.554	0.741	0.621	0.623	0.661	0.348	0.52	0.501
KTF2	0.455	0.221	0.647	0.663	0.563	0.516	0.626	0.677	0.436	0.537	0.699	0.87	0.452	0.497	0.401
KTF3	0.281	0.11	0.626	0.64	0.461	0.521	0.633	0.74	0.498	0.536	0.496	0.772	0.482	0.466	0.44
KTF4	0.324	0.135	0.493	0.608	0.489	0.469	0.616	0.647	0.419	0.357	0.542	0.845	0.493	0.467	0.402
KTF5	0.461	0.238	0.637	0.722	0.572	0.513	0.685	0.773	0.535	0.564	0.754	0.907	0.527	0.553	0.456
PO1	0.487	0.125	0.627	0.563	0.428	0.507	0.524	0.55	0.518	0.486	0.465	0.533	0.872	0.733	0.568
PO1	0.487	0.125	0.627	0.563	0.428	0.507	0.524	0.55	0.518	0.486	0.465	0.533	0.872	0.733	0.568
PO2	0.525	0.064	0.407	0.458	0.313	0.492	0.531	0.535	0.392	0.38	0.464	0.451	0.876	0.732	0.566
PO2	0.525	0.064	0.407	0.458	0.313	0.492	0.531	0.535	0.392	0.38	0.464	0.451	0.876	0.732	0.566
PO3	0.593	0.296	0.277	0.534	0.575	0.454	0.617	0.496	0.597	0.549	0.54	0.446	0.785	0.759	0.595
PO3	0.593	0.296	0.277	0.534	0.575	0.454	0.617	0.496	0.597	0.549	0.54	0.446	0.785	0.759	0.595
TS1	0.524	0.418	0.252	0.482	0.598	0.432	0.608	0.382	0.596	0.45	0.373	0.372	0.47	0.709	0.832
TS1	0.524	0.418	0.252	0.482	0.598	0.432	0.608	0.382	0.596	0.45	0.373	0.372	0.47	0.709	0.832
TS2	0.519	0.188	0.608	0.584	0.492	0.524	0.679	0.578	0.545	0.479	0.43	0.561	0.683	0.798	0.87
TS2	0.519	0.188	0.608	0.584	0.492	0.524	0.679	0.578	0.545	0.479	0.43	0.561	0.683	0.798	0.87

4.3.2 Assessment Structural Model

The outcome of the analysis is the effect of designer knowledge factors on the project performance. Project performance (design package) is called “Endogenous Variable”. While all the other Knowledge Management (latent variables) are called “Exogenous Variable”. Hair et al. (2011) studied researches which used structural equation modeling and came up with a program that does the calculation automatically by computer software. Hair et al. (2011) described five tests to assess the structural model as explained in sub-sections 4.4.2.1 ~4.4.2.5.

The assessment involved the following inspections (Rahman, I.A. et.al 2022);

1. Path relationship strength
2. Coefficient of determination
3. Goodness-of-fit (GoF)
4. Hypotheses of the paths

• Path Relationship Strength

According to Hair et al. (2019), path coefficients is measured with beta (β) value that reflect is the strength of the path or relationship between exogenous and endogenous constructs with values approximately between -1 and $+1$ (values can be smaller/larger but usually fall in between these bounds). Path coefficients values close to $+1$ represent strong positive relationships and vice versa for negative values that are usually statistically significant. The closer the estimated coefficients are to 0 , the weaker are the relationships. The generated path coefficients or beta values of the model are extracted from the software and tabulated as in table 4.9:

Table 4.11 shows that beta values of four relationships. According to Hair et al. (2017), β value should be above 0.1 regardless its signage either positive or negative. Thus, knowledge technology factor (KTF) construct is having the strongest while knowledge education factor (KEF) construct is the weakest relationship to the project performance (design package) construct, therefore confirming a weaker relationship between the knowledge education and project performance.

Table 4-11: Cross-loading Values

Construct	Path coefficients
DK -> KAF	0.214
DK -> KCF	0.352
DK -> KEF	0.506
DK -> KFF	0.297
DK -> KLF	0.388
DK -> KPF	0.333
DK -> KQF	0.537
DK -> KRF	0.504
DK -> KSF	0.347
DK -> KTF	0.157
KAF -> Project Performance	0.135
KCF -> Project Performance	0.373
KEF -> Project Performance	0.609
KFF -> Project Performance	0.141
KLF -> Project Performance	0.436
KPF -> Project Performance	0.086
KQF -> Project Performance	0.085
KRF -> Project Performance	-0.150
KSF -> Project Performance	0.164
KTF -> Project Performance	-0.355
Project Performance -> CS	0.847
Project Performance -> PO	0.878
Project Performance -> TS	0.888

- **Coefficient of Determination (R²)**

Using linear regression statistics, the “coefficient of determination (R²)” indicates the percentage by which exogenous factors explain the ultimate endogenous variables. To demonstrate, this value indicates the predictive and explanatory power of the model. 0 to 1 is the range of the coefficient of determination. However, the determination of what proportion is acceptable is entirely contextual.

Coefficient of determination is also known as R^2 which can be viewed as the combined effect of the exogenous variables on endogenous variables of the model. The R^2 values ranges from 0 to 1 with value closer to 1 representing complete predictive accuracy. This study adopted the R^2 threshold value by Cohen (1988) which R^2 value of 0.26 is considered as substantial, R^2 value of 0.13 is regarded as moderate, and R^2 value of 0.02 is considered as weak. The R^2 value for this model is extracted from the final model generation using PLS Algorithm function in SmartPLS software which is equal to 0.687 and considered as substantial effect.

- **Goodness of Fit of the model (GOF)**

The observed correlation and the indicated correlation in the model are used by GOF to assess how well the proposed model structure fits the actual data. The optimum statistical method to assess GOF has been the topic of debate among researchers. Researchers often utilize one of the following four approaches:

1. “The goodness of Fit Index (Henseler & Sarstedt, 2012)”
2. “Standardized Root Mean Square Residual (SRMR) (Henseler et al., 2015)”
3. “Root Mean Square Residual Covariance (Henseler et al., 2015)”
4. “Exact Fit Test (Dijkstra et al., 2015) ”

The value that is larger than zero is deemed to be a right fit for the model according to what is utilized in PLS software, and what is advised by the developer Hair. Regardless of all debates and the best method to obtain GOF. The number, however, must not be greater than 0.12; otherwise, there is a poor match among the proposed structural model and the associated empirical data. Hence, for this model the average of AVE for the entire construct variable and the R^2 for all dependent constructs variables as in Table 4.12.

Table 4-12: Results of bootstrapping

Construct	Average variance extracted (AVE)	R ² Values
CS	0.715	687
DK	0.644	
KAF	0.885	
KCF	0.628	
KEF	0.83	
KFF	0.821	
KLF	0.639	
KPF	0.607	
KQF	0.711	
KRF	0.754	
KSF	0.813	
KTF	0.792	
PO	0.715	
TS	0.725	
Average	0.734	

The average of AVE for endogenous variable is 0.6875 and the average R² for all dependent variables is 0.720. Thus, the calculated, $GoF = \sqrt{0.734 \times 0.687} = 0.6872$. This indicates that the model is having global large/high validating power.

- **Hypothesis Testing (Path Coefficient)**

The path coefficient is the precise test required to demonstrate the link between all latent variables in the model. Typically, this test involves assessing the “p-value (probability value of extremism or rarer)”. In the report created by Smart PLS, the p-value is represented in a tabular format. After expanding the data and resampling them (from number of collected data to 5000), the p-value calculation is performed using a technique known as "Bootstrapping" in Smart PLS. The purpose of bootstrap is to expand the collected data (the Sample of x participants) to match the original possible population of the whole construction sector in order to compute any possible standard error in the sample collected.

After resampling the data, Smart PLS measures the t-value and automatically calculates the p-value based on the empirical data collected and the t-value extraction. After 10 obtaining the p-value and ensuring that its standard error is less than 5 percent, a recommendation on the relationship is made.

Table 4.13 provides the results of a proposition testing of the path coefficients for the constructs investigating the effect of designer knowledge factors on project performance. According to the PLS software, the results are presented for each path coefficient as follows:

1. Original sample (O): This column shows the path coefficient for each predictor variable in relation to the dependent variable (project performance) based on the original data.
2. Sample mean (M): This column shows the path coefficient for each predictor variable in relation to the dependent variable (project performance) based on the sample mean.
3. Standard deviation (STDEV): This column shows the standard deviation for each predictor variable.
4. T statistics ($|O/STDEV|$): This column shows the T statistics for each predictor variable, which is the ratio of the path coefficient to the standard deviation. The significance of the path co-efficient is tested using this.
5. P values: This column shows the p-value for each predictor variable. A p-value less than 0.05 shows that the path coefficient is statistically significant.

The hypothesis testing results show that nine of ten constructs are significant which are having p-value above the cut-off value of 0.05. The significant relationships KSF, KCF, KFF, KLF, KRF, KSF, KPF, KQF and KTF toward project performance. Unfortunately, the other exogenous construct (KAF) is not significant, and this is due to the characteristics of the collected data which is not strong enough to establish significant relationship as what been hypothesized, which can be described in the P value being more than 0.05 with a value of 0.064, therefore proving a non-significant relationship between the acquisition factor and its effect of the construction knowledge of the designer.

In summary, the results of the hypothesis testing indicate that Knowledge management factors have a positive and statistically significant effect on project performance (design package) and that some factor may have a stronger effect than others. These findings may have important implications for organizations seeking to develop and assess knowledge in their designers.

Table 4-13: Hypothesis testing of the path coefficients.

Relationship	Standard deviation (STDEV)	T statistics (O/STDEV)	P values	Decision
KAF -> Knowledge Management	0.149	1.440	0.150	<i>Not Significant</i>
KCF -> Knowledge Management	0.186	1.896	0.048	<i>Significant</i>
KEF -> Knowledge Management	0.098	5.173	0.000	<i>Significant</i>
KFF -> Knowledge Management	0.146	2.029	0.042	<i>Significant</i>
KLF -> Knowledge Management	0.141	2.747	0.006	<i>Significant</i>
KPF -> Knowledge Management	0.152	2.188	0.029	<i>Significant</i>
KQF -> Knowledge Management	0.119	4.500	0.000	<i>Significant</i>
KRF -> Knowledge Management	0.111	4.544	0.000	<i>Significant</i>
KSF -> Knowledge Management	0.142	2.447	0.014	<i>Significant</i>
KTF -> Knowledge Management	0.165	1.953	0.034	<i>Significant</i>

4.3.3 Assessment of Mediation

When a phenomenon or a desired outcome is explained, usually all of the factors that might contribute to that outcome are studied. Many researchers have utilized Knowledge Management Factors as a variable to explain and obtain a percentage of influence on the improvement of project performance (design package) in the construction sector. They began investigating if Knowledge Management Factors had a direct impact on and explain for project performance. As their research progresses, interest in this field of study grows and more researchers demonstrate the presence of an Knowledge Management Factors-Project performance (design package) correlation.

This resulted in the discovery of additional explanatory factors called "Mediators". Mediators are a process that explains the causal relationship on the subject of "How the cause (Knowledge Management Factors) and the effect (Project performance) relationship are related. The solution is through the mediators of the causal link" Knowledge Leadership Factor (KLF), Knowledge Culture Factor (KCF), Knowledge Technology Factor (KTF), Knowledge Process Factor (KPF), Knowledge Acquisition (KAF), Knowledge Sharing (KSF), Knowledge Retention (KRF), Knowledge Education (KEF), Knowledge Financing (KFF), Knowledge Quality (KQF).

- **Approaches to Testing Mediation**

Baron et al. (1986) was the first to investigate the indirect association between variables via the mediation role effect. They offer four techniques to do this: 1) The initial indirect path estimate among the independent variable (Knowledge Management Factors) and the dependent variable (Work Attitudes) should be substantially different from zero; 2) The estimated second indirect path among the independent variable (Work Attitudes) and the dependent variable (Project Performance) must be significantly different from zero; 3) The impact of the direct link between (Knowledge Management Factors) must be reduced with the presence of a mediator; 4) With the mediator included, the estimate of the direct path must be non-significant. Without the mediator, the estimate of the direct path must be significant. The "Sobel Test" is performed after all prior processes have been checked and

satisfied. Using a statistical method known as the t-test, this test is performed to know if there is a significant decrease in the direct association when the mediator exists.

Preacher & Hayes (2008) proposed what is known as "The mediation Package" among scholars; this technique use the bootstrap method to determine the power limitation of the Sobel test. It employs a random sample size segmentation with a suggestion of "5000 sample size," allowing for the acquisition of data from tiny sample size results. For decades, scholars have used this strategy extensively. This study will follow the research leads from the previous decades and will utilize the "The mediation Package", which identifies two processes to evaluate the mediation, known as Bootstrap the bootstrap confidence and the interval indirect impact.

4.3.4 Bootstrap the Indirect Effect

This value will be calculated using PLS software that measures the indirect “P-Value” which reflects the relationship between Knowledge Management Factors and Project performance. The results indicate that all the independent variables have a significant indirect influence on project performance. The mediating variables also have significant indirect impacts on project performance. KTF has the most significant indirect effect on project performance (design package) among the mediating variables. In conclusion, the results shown in table 4.14 suggest that Knowledge Management Factors play an important role in enhancing project performance. The results highlight the value of developing competencies related to managerial skills, communication skills, emotional intelligence, and other designer skills to improve project performance.

- **Bootstrap Confidence Interval**

The confidence interval has a value between -1 and +1. It might be larger or smaller, that would occur in rare occasions (Hair et al., 2011). To have a latent variable that acts as a mediator, the distribution's upper limit (UL) and lower limit (LL) should be in the same direction of either positivity or negative. If one of the limits is positive and the other is negative, which means it encompasses the zero between the two limits, the model considers it irrelevant and has no mediation to the Knowledge Management Factors-Project performance (design package)correlation.

Table 4.14 represents the Bootstrap Confidence Intervals for the coefficients in a partial least squares (PLS) regression analysis of the impact of designer knowledge factors on project manager performance. The Bootstrap Confidence Intervals provide a range of plausible values for each coefficient based on resampling the original data.

Each row in the table represents a different path in the PLS model, indicating the impact of one variable (the independent variable) on another variable (the dependent variable). The columns provide the following information:

1. Original sample (O): the coefficient estimates from the original sample.
2. Sample mean (M): the mean of the coefficients estimated from the resampled data sets
3. Bias: the difference between the sample mean and the original sample estimate, indicating the presence of bias in the estimate 2.50%: the lower limit of the 95% Bootstrap Confidence Interval 97.50%: the upper limit of the 95% Bootstrap Confidence Interval.

In interpreting the table, we can focus on the Bootstrap Confidence Interval column, which indicates the range of values within which it can be confidently said that the true coefficient lies. If the confidence interval does not include zero, it can be concluded that the impact of the independent variable on the dependent variable is statistically significant at the 95% confidence level.

Likewise, the Bootstrap Confidence Intervals for all the other paths in the model can be interpreted. It is important to note that some of the confidence intervals include zero, indicating that the impact of the independent variable on the dependent variable is not statistically significant. The Bias column indicates the presence of bias in some of the coefficient estimates, which can be due to the smaller sample size or other issues with the data.

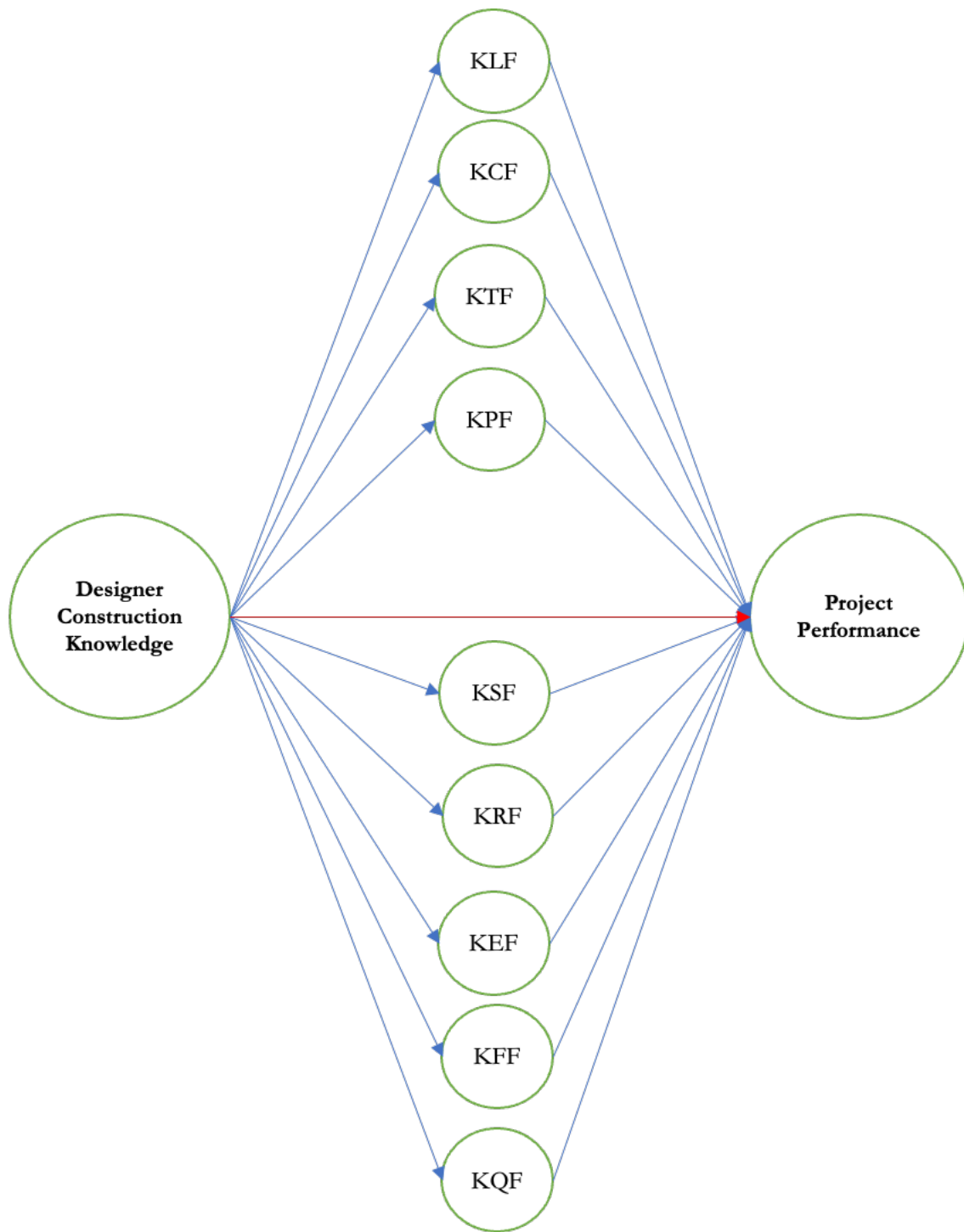
Table 4-14: Bootstrap Confidence Intervals

Construct	Original sample (O)	Sample mean (M)	Bias	2.50%	97.50%	Decision
DK -> KAF	0.214	0.216	0.002	-0.238	0.428	Reject
DK -> KCF	0.352	0.343	-0.009	0.481	0.545	Accept
DK -> KEF	0.506	0.526	0.020	0.263	0.650	Accept
DK -> KFF	0.297	0.300	0.003	0.080	0.529	Accept
DK -> KLF	0.388	0.396	0.008	0.008	0.585	Accept
DK -> KPF	0.333	0.338	0.005	0.315	0.523	Accept
DK -> KQF	0.537	0.547	0.009	0.255	0.720	Accept
DK -> KRF	0.504	0.521	0.016	0.213	0.664	Accept
DK -> KSF	0.347	0.353	0.006	0.007	0.573	Accept
DK -> KTF	0.157	0.157	0.000	0.304	0.415	Accept
KAF -> Project Performance	0.135	0.136	0.000	-0.158	0.447	Reject
KCF -> Project Performance	0.373	0.350	0.023	0.263	0.913	Accept
KEF -> Project Performance	0.009	0.001	0.008	0.361	0.394	Accept
KFF -> Project Performance	0.141	0.132	0.009	0.099	0.419	Accept
KLF -> Project Performance	0.436	0.424	0.012	0.089	0.870	Accept
KPF -> Project Performance	0.086	0.077	0.009	0.340	0.616	Accept
KQF -> Project Performance	0.085	0.117	0.032	0.251	0.544	Accept
KRF -> Project Performance	0.150	0.159	0.010	0.516	0.235	Accept
KSF -> Project Performance	0.164	0.182	0.018	0.157	0.496	Accept
KTF -> Project Performance	0.355	0.334	0.020	0.817	0.088	Accept
Project Performance -> CS	0.847	0.841	0.006	0.580	0.944	Accept
Project Performance -> PO	0.878	0.878	0.000	0.778	0.930	Accept
Project Performance -> TS	0.888	0.889	0.000	0.789	0.936	Accept

- **Knowledge Management Final Model**

In the current study, aim is to investigate the impact of knowledge management of construction designers within the construction industry. To achieve this, first a comprehensive knowledge management model was developed accordingly to measure the effect of KM on the project performance. Following the development of this model, a questionnaire was constructed to gather data from industry professionals which allowed to assess the relevance and applicability of the proposed competencies. Subsequently, Partial Least Squares (PLS) software was utilized to validate the model and analyze the results as shown in figure 4.10.

Remarkably, the findings demonstrated that all constructs but one within the model meet the established criteria, indicating a strong and robust relationship between knowledge management factors and project performance. This outcome shown in Figure 4.9 which is the final conceptual model of the Designer knowledge suggests that the developed knowledge management model is well-suited for the construction industry, and no adjustments are necessary to enhance its effectiveness in predicting project success.



[Figure 4.9: Knowledge Management Final Conceptual Framework]

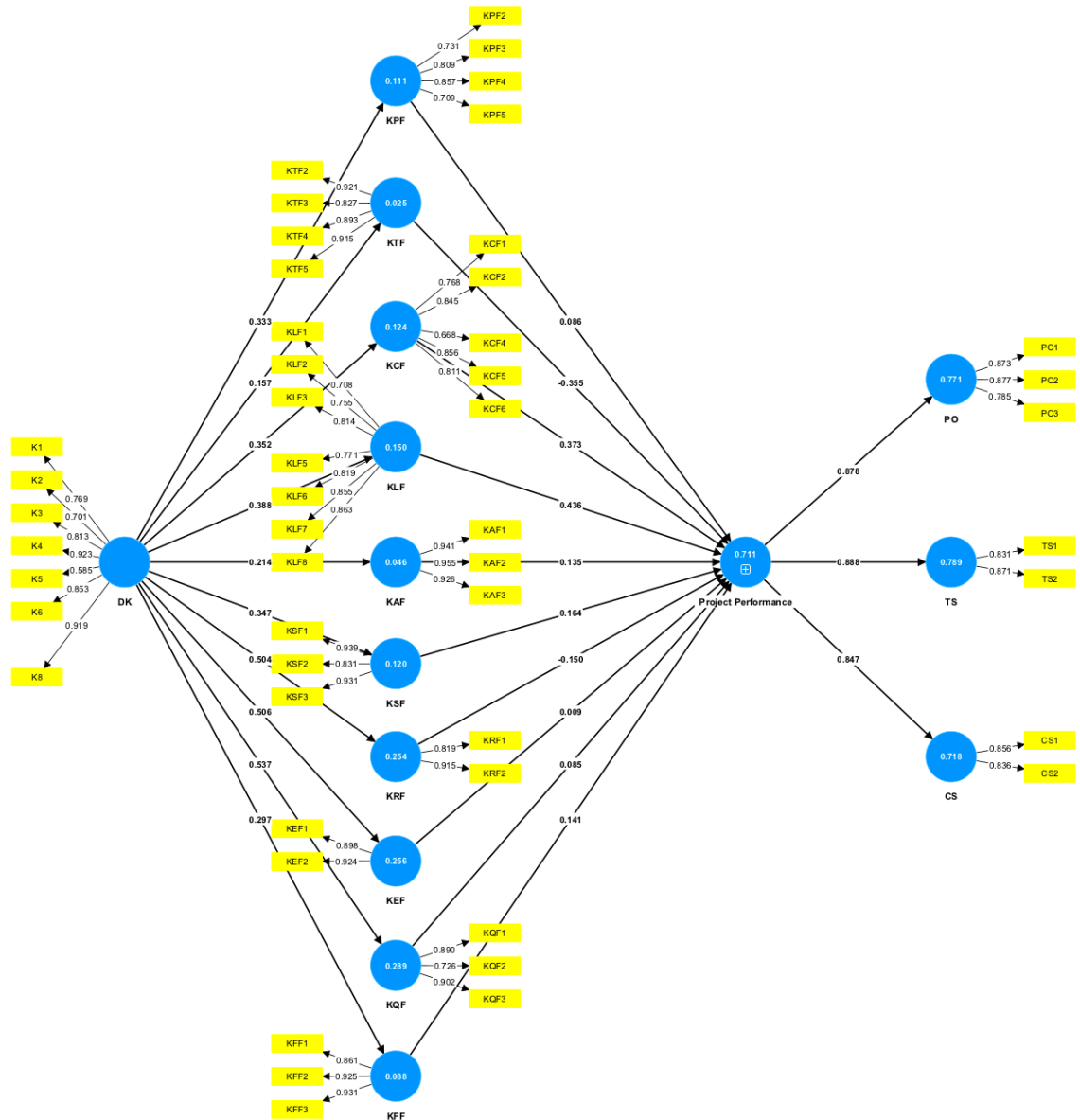


Figure 4.10: Knowledge Management Final mode (Smart-PLS)

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Overview

This chapter presents a summary of the study, which aims to explore the impact of Designer knowledge Factors on project performance (design package) within the construction industry. The primary goal of this research is to pinpoint the crucial designer knowledge mediators that contribute to successful project outcomes and to comprehend their influence on project performance. To accomplish this goal, a quantitative research method is utilized, incorporating data from a survey of construction industry professionals.

Section 5.2 presents the findings of this study while directly addressing the research questions. These findings offer insights into the specific knowledge management factors that significantly affect project performance (design package) in the construction industry. Additionally, section 5.2 will report on minor findings that emerged during the research process. Although these findings may not directly answer the research questions, they provide valuable insights and contribute to a more comprehensive understanding of the topic. Section 5.3 draws a conclusion regarding the impact of knowledge management on project performance (design package) in the construction industry. This section provides key insights obtained from the research and emphasizes their implications for both theory and practice.

In section 5.4 recommendations for various stakeholders in the construction industry, such as designers, team members, and organizational leaders, are provided. These recommendations are based on the study's findings and offer practical guidance on enhancing project performance (design package) through better knowledge management.

Lastly, section 5.5 concludes with recommendations for future research in the area of knowledge management and project performance (design package) in the construction industry. These recommendations identify potential avenues for further investigation and suggest ways in which future studies can build upon the findings of this research.

5.2 Summary of the Study

This study aims to investigate the relationship between knowledge management and project performance (design package) in the construction industry. The research problem is the lack of understanding of the essential knowledge and skills needed to succeed in creating comprehensive design management framework that reflect the relationship between knowledge management and project performance (design package). The research objectives are to construct and validate a knowledge management Framework for designers and to identify the relation between knowledge management and project performance (design package).

The significance of this study resides in its provision of a structured framework tailored for organizations operating within the construction industry and other pertinent sectors. The framework outlined herein serves as a pivotal tool for assessing the depth and efficacy of designers' knowledge, as delineated within the model presented. While the specific factors and mediators may be subject to alteration, the fundamental concept of employing such a framework remains universally applicable and beneficial for gauging knowledge proficiency. Another significance lies in raising awareness about the importance of knowledge in project success and adding to the knowledge base in the area of knowledge management of designers, which can assist company owners in making key choices about the skills they need to learn to guide their firms in the right direction.

The research begins with an extensive literature review to identify gaps in knowledge related to Designer knowledge in the project performance (design package) within the construction field. A comprehensive Knowledge Management model is developed, and data is collected from grade 1 and grade 2 design offices from the Eastern Province of Saudi Arabia through a questionnaire. Partial Least Squares (PLS) analysis is employed to validate the Knowledge Management model and analyze the results, leading to the establishment of a final Framework.

5.3 Findings

Based on the results of the study, the following are the major findings that directly answer the research questions.

1. **Knowledge Management Dimensions:** The knowledge management dimensions are Knowledge Leadership Factor (KLF), Knowledge Culture Factor (KCF), Knowledge Technology (KTF), Knowledge Process (KPF), Knowledge Acquisition Factor (KAF), Knowledge Sharing Factor (KSF), Knowledge Retention Factor (KRF), Knowledge Education Factor (KEF), Knowledge Financing Factor (KFF), Knowledge Quality Factor (KQF).
2. **Effect Size Values:** Knowledge Leadership Factor (KLF) has the highest effect size values, indicating a strong positive impact on project performance (design package).
3. **Positive Impact Factors:** Other factors such as Knowledge Financing Factor (KFF), Knowledge Education Factor (KEF), and Knowledge Sharing Factor (KSF) also have a strong positive impact on project performance (design package).
4. **Moderate Impact Factors:** Knowledge Culture Factor (KCF), Knowledge Process (KPF), and Knowledge Retention Factor (KRF) have a moderate effect on project performance (design package).
5. **Insignificant Factors:** Knowledge Acquisition Factor (KAF) and Knowledge Quality Factor (KQF) were not significant enough and they don't have a significant effect on project performance (design package).

6. **Statistical Significance:** Nine out of the ten predictor variables have a statistically significant positive effect on project performance, while (KAF) didn't.
7. **Variance Explained:** Customer satisfaction and Project Objectives have the highest amount of variance explained by their respective indicators, suggesting that improving these aspects may lead to better project performance.
8. **Strategic Prioritization:** Prioritizing the most effective knowledge management factors can help organizations optimize their resources and efforts to achieve better project outcomes in the construction industry.

5.4 Conclusion

The knowledge management of construction designers have a direct impact on project performance (design package), either directly or through defined moderators. These moderators include education, sharing of knowledge, culture, leadership, and others.

In conclusion, this study represents a significant contribution to the understanding of the intricate relationship between knowledge management and project performance (design package) within the construction industry. The research set out to address the critical issue of the insufficient comprehension of the essential knowledge and skills necessary for developing comprehensive design management Frameworks that effectively capture the interplay between knowledge management and project performance.

The findings of this study, offer a nuanced understanding of the major dimensions of knowledge management, each playing a distinctive role in influencing project performance (design package). Notably, the Knowledge Leadership Factor (KLF) and Knowledge Technology Factor (KTF) emerge as pivotal dimensions with the highest effect size values, signifying a robust positive impact on project outcomes. Additional factors such as Knowledge Financing Factor (KFF), Knowledge Acquisition Factor (KAF), and Knowledge Sharing Factor (KSF) also exhibit significant positive effects on project performance.

While Knowledge Culture Factor (KCF), Knowledge Process Factor (KPF), and Knowledge Retention Factor (KRF) exert a moderate influence, Knowledge Education Factor (KEF) and Knowledge Quality Factor (KQF) do not demonstrate a statistically significant effect on project performance (design package). Nevertheless, the collective positive impact of all predictor variables underscores the overarching importance of knowledge management in enhancing project outcomes.

The findings further highlight the critical role of customer satisfaction and adherence to project objectives in determining project success, as evidenced by their high variance explained by respective indicators. As organizations navigate the complex landscape of the construction industry, prioritizing the most effective knowledge management factors identified in this study becomes instrumental in optimizing resources and efforts for superior project outcomes.

In essence, this research provides actionable insights for designers, organizational leaders, and stakeholders in the construction industry, offering a roadmap for bolstering project performance through strategic knowledge management practices. The identified knowledge dimensions and their varying impacts contribute substantively to both theoretical understanding and practical application, fostering a more informed approach to decision-making in the realm of construction project management. As the industry evolves, the implications of this study resonate as a valuable guide, informing future endeavors and advancements in the dynamic intersection of knowledge management and project performance.

5.5 Recommendations

The following recommendations are based on the findings of the study and are intended for various stakeholders in the construction industry, including designers, team members, organizational leaders, and educators. These recommendations aim to guide practices and strategies that enhance project performance (design package) through effective knowledge management.

A. Designers:

- **Continuous Professional Development:** Designers are advised to prioritize continuous professional development, particularly in areas related to Knowledge Leadership (KLF) and Knowledge Technology (KTF). This includes staying updated on industry trends, emerging technologies, and leadership skills to contribute effectively to project success.
- **Collaboration and Knowledge Sharing:** Encourage a culture of collaboration and knowledge sharing within design teams. Establish platforms or forums that facilitate the exchange of ideas, experiences, and best practices among team members to enhance Knowledge Sharing (KSF) and overall project performance.
- **Embrace Technological Solutions:** Embrace and leverage technology to improve design processes. Designers should explore and adopt technologies that align with Knowledge Technology (KTF), as identified in the study, to streamline workflows and enhance the efficiency of design activities.

B. Organizational Leaders:

- **Leadership Development Programs:** Invest in leadership development programs that specifically target Knowledge Leadership (KLF). Fostering strong leadership skills among organizational leaders can positively impact project performance by providing clear direction and strategic guidance.
- **Resource Allocation:** Strategically allocate resources based on the identified impact factors. Prioritize investments in areas such as Knowledge Financing (KFF), Knowledge Acquisition (KAF), and Knowledge Sharing (KSF) to maximize their positive influence on project outcomes.
- **Knowledge Management Policies:** Develop and implement clear knowledge management policies within the organization. These policies should address the dimensions of Knowledge Culture (KCF), Knowledge Process (KPF), and Knowledge Retention (KRF) to create a supportive environment for effective knowledge management.

C. Educators:

- **Curriculum Enhancement:** Incorporate relevant knowledge management concepts into educational curricula for designers. Ensure that educational programs emphasize the importance of Knowledge Education (KEF) and equip future professionals with the necessary skills to contribute to successful project outcomes.
- **Practical Application:** Integrate practical applications of knowledge management principles into educational modules. Provide opportunities for students to engage in real-world scenarios that simulate the challenges and opportunities associated with knowledge management in the construction industry.

D. Industry Stakeholders:

- Collaboration Platforms: Establish industry-wide collaboration platforms that enable knowledge exchange and collaboration among different stakeholders. This can enhance collective learning and contribute to the improvement of overall project performance in the construction sector.
- Continuous Research and Innovation: Encourage and support ongoing research initiatives focused on knowledge management and project performance in construction. Continuous exploration of new methodologies, technologies, and best practices will contribute to the evolution of the industry.

E. Further Research:

- Exploration of Insignificant Factors: Conduct further research to explore the reasons behind the insignificance of Knowledge Education (KEF) and Knowledge Quality (KQF) factors. Understanding these aspects can provide insights into potential adjustments or enhancements in these areas.
- Longitudinal Studies: Undertake longitudinal studies to track the long-term impact of knowledge management practices on project performance. This will provide a deeper understanding of the sustained effects of implementing specific knowledge management strategies.
- Different Industries: Extend the analysis to different industries to assess the transferability and effectiveness of knowledge management practices across various sectors. This comparative study can uncover industry-specific challenges and opportunities for optimizing knowledge management strategies.

In conclusion, these recommendations are tailored to support stakeholders in the construction industry in optimizing knowledge management practices for improved project performance. By implementing these suggestions, stakeholders can contribute to the advancement of the industry and foster a culture of continuous improvement and innovation.

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Vitae

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Appendix A

Thesis Survery

The objective of this research is to find the knowledge areas that a designer must acquire to produce integrated design solutions for buildings. I am approaching you to help us defining those areas of knowledge by providing the requested information in the attached questionnaire. Completing the questionnaire will not take more than 15 minutes of your time. We assure you that the provided data will be treaded under extreme confidentiality and will be reported in aggregates. We thank in anticipation of your valuable participation.

This research will have a restricted focus on prominent consulting firms that specialize in the creation of building structures and are situated in Saudi Arabia

* Required

Profile Background

1. Gender *

☐ Male

☐ Female

2. Age *

☐ 20 to less than 30

☐ 30 to less than 40

☐ 40 to less than 50

☐ 50 and older

3. Education *

☐ Highschool or Diploma

☐ BSc

☐ MSc

☐ PHD

☐ Other

4. Experience Level (Construction Industry) *

- ☐ Less than 5 years
- ☐ 5 to less than 10 years
- ☐ 10 to less than 15 years
- ☐ 15 years or more

5. Department *

- ☐ Architecture
- ☐ Engineering
- ☐ Project Management
- ☐ Other

6. Employer *

- ☐ Consulting Office
- ☐ Contractor
- ☐ Other

7. Position *

- ☐ Architect/Designer
- ☐ Design Lead
- ☐ Project Manager
- ☐ Design Engineer
- ☐ Owner

8. Company Field (You may select more than one answer) *

- ☐ Residential Construction
- ☐ Building Construction
- ☐ Design Office
- ☐ Other

9. Average Designed Project Size (SAR) *

- ☐ Less than 50 million
- ☐ 50-150 million
- ☐ 150-250 million
- ☐ More than 250 million

Measuring Designers Knowledge

10. Measuring Knowledge of Designers, on a scale of 1-5 ? *

	1	2	3	4	5
Design Codes Mastery: Proficiency in understanding, interpreting, and applying relevant design codes, ensuring compliance and adherence to industry standards in the creation of designs.	☐	☐	☐	☐	☐
Regulatory Compliance: Knowledge of and adherence to local, national, and international regulations and building codes governing design practices, ensuring designs meet legal requirements and safety standards.	☐	☐	☐	☐	☐
Digital Design Proficiency: Competency in leveraging digital design tools and technologies, such as CAD (Computer-Aided Design) software, to create precise and visually compelling design representations, Mastery in utilizing BIM tools and methodologies for collaborative and efficient design processes, ensuring accurate representation and integration of design elements.	☐	☐	☐	☐	☐
Risk Assessment and Mitigation: The ability to identify potential risks in the design process and implement strategies to mitigate these risks, ensuring the successful execution of design projects.	☐	☐	☐	☐	☐
Cultural Sensitivity in Design: Recognition and incorporation of cultural considerations in design, ensuring designs align with and respect the cultural context of the construction project.	☐	☐	☐	☐	☐
Adaptability to Technological Advances: Openness to adopting and adapting to emerging technologies in the construction and design industry, ensuring designs remain current and aligned with industry trends.	☐	☐	☐	☐	☐
Client-Centric Approach: A focus on understanding and addressing client needs and preferences, incorporating client feedback into the design process to enhance overall satisfaction.	☐	☐	☐	☐	☐
Continuous Learning and Professional Development: Commitment to ongoing learning and professional development to stay abreast of industry advancements, trends, and evolving design methodologies.	☐	☐	☐	☐	☐

Measuring Knowledge Management

Mediators:

The followings are Knowledge mediators. You are kindly requested to assess each factor and its affect on the Designer's Knowledge by placing a tic in the appropriate box next to each factor.

11. Knowledge Process *

	Strongly Agree	Agree	Neutral	Disagr
Provide training/instruction as normal work practices to project team members.	☐	☐	☐	☐
Processes for documenting lessons learned are regularly improved and updated.	☐	☐	☐	☐
Processes for searching for lessons learned are regularly improved and updated.	☐	☐	☐	☐
Ability to provide knowledge that others need.	☐	☐	☐	☐
Provide valuable knowledge for carrying out projects.	☐	☐	☐	☐

12. Knowledge Technology *

	Strongly Agree	Agree	Neutral	Disagr
Make use of technology to access knowledge in performing projects.	☐	☐	☐	☐
Use technologies that allow them to share knowledge about projects within or outside the organization.	☐	☐	☐	☐
Participate in knowledge management technology activities such as searching, creating and others.	☐	☐	☐	☐
Actively share the project knowledge with others using available technology.	☐	☐	☐	☐
Encourage other project team members to apply knowledge technology	☐	☐	☐	☐

13. Knowledge Culture

	Strongly Agree	Agree	Neutral	Strongly D
Provides tangible incentives to encourage participation in project knowledge management activities.	☐	☐	☐	☐
Motivates employees to participate in project knowledge management activities.	☐	☐	☐	☐
Rewards employees who create, share, store and use knowledge to perform projects.	☐	☐	☐	☐
Values knowledge seeking and problem-solving.	☐	☐	☐	☐
Has a high level of trust among employees for sharing project knowledge	☐	☐	☐	☐
Encourages project team members to share mistakes about projects openly without the fear.	☐	☐	☐	☐

14. Knowledge Leadership *

	Strongly Agree	Agree	Neutral	Disagr
Organization encourages team members to participate in project knowledge management activities.	☐	☐	☐	☐
Organization supports team members to participate in project knowledge management activities.	☐	☐	☐	☐
Provide necessary help and resources to participate in project knowledge management activities.	☐	☐	☐	☐
Are keen to see that the employees happy to participate in project knowledge management activities.	☐	☐	☐	☐
Has sufficient resources in project knowledge management activities.	☐	☐	☐	☐
Has sufficient financial resources for building an ICT system to manage project knowledge.	☐	☐	☐	☐
Has sufficient skilled project team members to perform project knowledge management activities.	☐	☐	☐	☐
Provides time for project team members to perform project knowledge management activities.	☐	☐	☐	☐

15. Knowledge Acquisition *

	Strongly Agree	Agree	Neutral	Disagr
Processes for sharing lessons learned are widely accepted as part of normal work practices.	☐	☐	☐	☐
Strategies for capturing and creating knowledge in construction projects	☐	☐	☐	☐
Importance of knowledge acquisition from external sources (e.g., consultants, experts)	☐	☐	☐	☐

16. Knowledge Sharing *

	Strongly Agree	Agree	Neutral	Disagr
Communication and collaboration techniques for effective knowledge sharing	☐	☐	☐	☐
Role of technology in facilitating knowledge dissemination	☐	☐	☐	☐
Believe in sharing knowledge with others.	☐	☐	☐	☐

17. Knowledge Retention *

	Strongly Agree	Agree	Neutral	Disagr
Methods for storing and organizing tacit and explicit knowledge	☐	☐	☐	☐
Importance of capturing lessons learned for future projects	☐	☐	☐	☐

18. Knowledge Education *

	Strongly Agree	Agree	Neutral	Disagr
Importance of continuous learning and skill development	☐	☐	☐	☐
Training programs for enhancing knowledge management capabilities	☐	☐	☐	☐
Team dynamics and their influence on knowledge management practices	☐	☐	☐	☐

19. Knowledge Quality *

	Strongly Agree	Agree	Neutral	Disagr
Accuracy: Ensuring that the knowledge reflects the actual facts and information	☐	☐	☐	☐
Relevance: The degree to which the knowledge aligns with the specific context, goals, and needs	☐	☐	☐	☐
Usability: The practicality and applicability of the knowledge	☐	☐	☐	☐

20. Knowledge Financing *

	Strongly Agree	Agree	Neutral	Disagr
Cost of hardware, desktop, accessories, and networks	☐	☐	☐	☐
Cost of software procurement, implementation, and maintenances	☐	☐	☐	☐
Cost of knowledge management and operations	☐	☐	☐	☐

Measuring Project Performance

Mediators:

The followings are Project Performance mediators. You are kindly requested to assess each factor and its affect on the Project Performance by placing a tic in the appropriate box next to each factor.

21. Project Objectives *

	Strongly Agree	Agree	Neutral	Disagr
<u>Time</u> : All project tasks were executed according to the predetermined timetable	☐	☐	☐	☐
<u>Cost</u> : The project's overall budget closely matched the initial projections.	☐	☐	☐	☐
<u>Quality</u> : The project deliverables exhibited a high degree of reliability and demanded minimal maintenance.	☐	☐	☐	☐

22. Team Satisfaction *

	Strongly Agree	Agree	Neutral	Disagr
<u>Process Satisfaction</u> : All participants have had the chance to express their opinions regarding the project's objective or mission.	☐	☐	☐	☐
<u>Execution Satisfaction</u> : The project team expressed contentment with both the project's outcomes and the process of project management.	☐	☐	☐	☐

23. Client Satisfaction *

	Strongly Agree	Agree	Neutral	Disagr
Project tasks are executed precisely as outlined in the plan.	☐	☐	☐	☐
The project specifications successfully meet their intended objectives.	☐	☐	☐	☐

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