POLITECNICO DI TORINO

Master’s Degree in Engineering and Management

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The Impact of Integrated Supply Chain Platforms on Project Management Criteria: A Study of Time, Cost, Risk Management in Construction Projects

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Abstract

In an era where information is paramount, the evolving landscape of supply chain management (SCM) is recognized as pivotal for the competitiveness of the construction industry, notably within Germany.

This research examines the transformative potential of Integrated Supply Chain Platforms (ISCPs), leveraging empirical evidence from project managers and employing Structural Equation Modeling (SEM) for analysis. Focused on the project level, this study evaluates ISCPs' effectiveness in enhancing project management efficiency in time, cost, and risk management, highlighting the critical role of information technology in ensuring seamless information exchange. Our findings reveal a significant positive correlation between ISCP implementation and project outcome improvements, indicating substantial advancements in time management efficiency, cost control precision, and risk mitigation depth.

The research is informed by Doroudchi & Nikmehr (2007), Kashyap (2011), and Mashreghi & Nahavandi (2010), who underscore the strategic role of information in SCM and its dual function in operational organization and future demand anticipation. By offering a granular analysis of ISCP impacts on project-level performance, this study not only addresses existing knowledge gaps but also ushers in a new digital integration era within the construction industry's SCM practices.The implications of this work are manifold, extending beyond academia to provide actionable insights for industry practitioners keen on leveraging technology for project success and sustainability in the face of evolving challenges. Through a mixed-method approach, the indispensable role of information as a decision-making tool is underscored, empowering SC businesses to exert greater control over suppliers and enhance their SCM capabilities, thus affirming the foundational insights provided by the referenced works.

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Abbreviations

Abbreviation	Full Form
ERP	Enterprise Resource Planning
SC	Supply Chain
SCM	Supply Chain Management
SEM	Structural Equation Modeling
ISCP	Integrated Supply Chain Platform
ISCMP	Integrated Supply Chain Management Platform
TM	Time Management
CM	Cost Management
RM	Risk Management
PM	Project Management
SCV	Statistical Conclusion Validity
IT	Information Technology

Chapter 1
Introduction

1.1.Background

Information is now viewed as a key instrument in decision-making for the survival and growth of supply chain (SC) businesses. (Doroudchi & Nikmehr, 2007). Gaining power from information would likely allow businesses dealing with SC challenges to exert more control over their suppliers and improve their supply chain management (SCM) capabilities (Kashyap, 2011). [1]

In the supply chain, information is frequently used to achieve two objectives (Mashreghi & Nahavandi, 2010): 1. Organizing everyday operations related to manufacturing, storage, positioning, and transportation 2. Using forecasting and planning to predict future demand and determine the necessary steps to requirements. Effective information dissemination and transmission can enhance all SCM components. A key factor in improving SCM implementation is the use of information technology for accurate and timely information sharing and transfer.

Planning and operational decision-making can benefit greatly from accurate information. Earlier studies have extensively explored systems designed to consolidate internal data processing operations, merge operational data, and integrate enterprise functions (Adaileh & Abu-alganam, 2010)[2].

However, as businesses strive for greater integration and efficiency in their supply chain operations, a broader concept known as Integrated Supply Chain Management Platforms (ISCMPs) has gained prominence. These platforms transcend traditional systems, offering seamless integration not only within internal operations but also with external stakeholders, including customers and suppliers. ISCMPs serve as indispensable tools for achieving supply chain integrity by delivering accurate and timely information across the entire supply chain network.

Data produced by various functions is a valuable asset within enterprises. Integrated systems are widely utilized to establish seamless integration with customers, suppliers, or both, ensuring the delivery of accurate and timely information vital for maintaining supply chain integrity. These systems, as described by Kashyap (2011), encompass a collection of management tools aimed at balancing supply and demand. Moreover, they facilitate high levels of cross-functional integration across sales, marketing, and other departments, employing established business processes for effective decision-making. Additionally, these systems have the capability to connect buyers and sellers, thereby creating a seamless supply chain using proven commercial techniques[1].

Decision-making processes facilitate high levels of cross-functional integration across various departments, including sales, marketing, production, operations, logistics, purchasing, financing, new product development, and human resources. This integration aids businesses in managing their operations with heightened productivity and customer service while simultaneously reducing expenses and inventory, thereby laying the groundwork for successful e-commerce endeavors.

The examination of integrated systems effectiveness in the literature is typically divided into two components (Adaileh & Abu-alganam, 2010; Ifinedo & Nahar, 2009)[2], [3]:

- The technical effectiveness of system installation, encompassing project management indicators, time estimation, and cost estimation.
- The success elements of integrated systems within organizations post-adoption, focusing on their application to improve operational efficiency.

Drawing from the Delon and McLean (1992) model of information system success, which evaluates system quality, information quality, system use, user happiness, individual impact, and organizational effectiveness, Gable et al. (2003) developed a tailored framework for measuring integrated system success. Their model emphasizes factors such as organizational effectiveness, individual influence, system quality, and information quality, streamlining the assessment process while ensuring comprehensive evaluation[4], [5].

Several individuals view the construction industry, which is among the oldest in the world and is regarded as favorable, as troublesome and a complicated process that is challenging to manage. The construction sector still uses the majority of conventional techniques. According to recent studies, the construction sector is known for its poor performance and limited margins of profit (Cox and Ireland, 2002).[6] According to Josephson and Saukkoriipi (2005), waiting, handling materials, and other indirect labor accounted for more than 80% of the typical Swedish craftsman's working day. It indicates that methods for increasing productivity must be found.

Construction sector supply chains may be quite intricate. Particularly in a large-scale project, several suppliers and subcontractors may be involved. Any delay in the delivery of materials for a construction project might cause the work to be delayed, and if the work is vital, the project will probably get postponed as a result. As a result, in order to get the greatest outcomes upon completion of a construction project, managers must pay close attention when controlling the supply chain route. This must be done appropriately and successfully throughout the duration of the project. According to O'Brien and Fischer (1993), there is a strong probability of increasing construction project productivity by strengthening the supply chain throughout the project's life cycle. Consequently, many firms have reconsidered the need for cooperative, mutually beneficial supply chain partnerships and the improvement of inter-organizational processes in a joint manner has become a high priority. [7] The impact of the integration of the supply chain on different aspects, such as performance, resilience, etc., has been studied in different research projects and in different industries.

Digital platforms have grown exponentially in recent years, and hence, the need for intra and extra-firm integration has gained popularity accordingly. This need is at the heart of business. Kache and Seuring [5] the key to the success of the e-supply chain and efficiency is integration.

Additionally observed is that the integration of e-supply chains allows organizations to seamlessly exchange real-time information, enhancing productivity, efficiency, and the supply chain's capacity to deliver faster and superior products/services. It also helps in achieving a better balance between supply and demand while reducing costs through improved coordination and information sharing. The empirical evidence presented by Rai, Patnayakuni, and Seth [8]demonstrates that integrating supply chain processes enables firms to enhance their performance, particularly in terms of operational excellence and increased revenues. Furthermore, a survey conducted by European A.T. Kernrney/WHU Logistics among European supply chain managers found that approximately 80 percent of the participants acknowledged the significance of integration for the digitalization of their supply chains. Thus, the requirement for integration significantly contributes to the concept of DSC.

Digital technologies can improve supply chain processes to guarantee a prompt response to customer needs. This is achievable because smart products, such as smartphones, tablet computers, and handheld devices, have the capability to convert electronic messages needed by current systems and facilitate electronic data communication between the company and other members of the supply chain. Xue, Zhang, Ling, and Zhao define the digital supply chain (DSC)[9] as a set of inter-organizational systems (IOSs) that companies adopt to digitize transactional and collaborative processes with their supply chain partners, including upstream suppliers and downstream customers.

According to Farahani et al., the primary technological advancements with the most significant impact on the digital supply chain are big data and cloud computing. [10]

1. Big data: Big data plays a crucial role in enhancing visibility within the supply chain by offering an integrated platform for real-time data analysis, performance tracking, and informed decision-making scenarios. This, in turn, reduces the likelihood of disruptions and delays in the supply chain [11].

2. Cloud computing: Cloud technology enables the storage and real-time processing of large data volumes, making information accessible to all participants in the supply chain [12]. Compared to traditional IT solutions, cloud technologies facilitate swift acquisition and deployment without necessitating extensive changes

or expansions to a company's existing infrastructure [13], allowing for adaptable and agile operations.

According to Deloitte AG in 2015, incorporating advanced technology into businesses is crucial for enhancing productivity. This integration can result in various benefits, such as reducing operational costs, increasing customer satisfaction, and improving client retention. Moreover, it plays a significant role in establishing an efficient, adaptable, and responsive supply chain, which leads to shorter lead times and greater product availability. Lindgren (2015) further emphasized that having the courage to abandon outdated operating models is a crucial factor in achieving success. [14]

According to a study conducted by Büyüközkan and Göçer in 2018, there is a significant research gap when it comes to real-life applications of digital supply chain (DSC)[15], particularly within the manufacturing sector. They also noted that different companies in various industries have their own unique policies, approaches, and practices for implementing DSC. Therefore, further research is necessary to develop specific sub-frameworks for DSC in each industry. These sub-frameworks would help enhance the important trends for future DSC. Several studies have suggested that digitalization plays a crucial role in improving supply chain operations. Hence, having a proper guideline and framework for implementing DSC is essential to facilitating this digital transformation.

Bhargava et al. (2013) conducted a study which defined digital supply chain (DSC) as a combination of systems that facilitate communication and transactions between global distribution organizations and their partners in supply chains[16]. This definition was further supported by Cecere (2016)[17]. Kinnet (2015) emphasized that DSC is characterized by speed, intelligence, and value creation throughout the entire chain. With the advent of new technologies and advanced analysis methods, DSC has the potential to generate new sources of revenue, returns, and profits. Schrauf and Berttram (2016)[18] also argued that digitalization not only adds value to supply chains but also enables them to offer more accessible and affordable services. Israelit et al. (2018) conducted a similar study and found that companies that integrate digital technologies into their supply chains can enhance service levels rapidly. By implementing a digitalized and fully integrated supply chain network, businesses can respond swiftly to customer demands while improving effectiveness, efficiency, and overall productivity. McKinsey Digital (2015) stated that DSC allows manufacturers to gain a deep understanding of customer behavior and establish a unique position within a complex ecosystem of partners, suppliers, and customers.

According to a 2015 study by Porter and Heppelmann, digitalization is anticipated to play an increasingly significant role in the management and design of global supply chains, particularly those that supply companies that are actively engaged in value-adding activities, such as those involved in production and logistics systems.[19] Digitalization, in the opinion of Büyüközkan and Göçer (2018)[15], is the DSC's first phase. Digitalization is defined as the use of digital technology and the transition of traditional businesses to digital businesses, which results in the creation of new sources of income. According to Isaksson, Wennberg, Se, and Se (2016)[20], digitalization is a technological force that strengthens globalization in both economic and cultural aspects. Digital operations, digital organization and culture, and digitalization strategy can be divided into three essential stages (Corver & Elkhuizen, 2014)[21].

The process of digitization can be divided into three essential stages: digitalization strategy, digital organization and culture, and digital operations (Corver & Elkhuizen, 2014)[21]. The digitalization strategy focuses on establishing digital goals, formulating a digital strategy, and implementing it. Simultaneously, the digital organization and culture stage involves analyzing the current organizational and cultural aspects, managing the digital transformation of the organization and culture, and transitioning them into a digital state. On the other hand, digitalization operations emphasize enabling workers, managing digital operations, and implementing digital operations effectively.

The basic Supply Chain Management (SCM) techniques have been extensively used in the production industry and they are finding their way in the construction industry as well. The earliest documented account of the construction supply chain has been reported to coordination, costing, and control in construction (O'Brien, 1995)[22]. It has been reported by researchers that the application of SCM can result in better coordination, costing, and control in the construction industry. A better understanding of a firm's production costs and capabilities, in particular their ability to manage their resources across projects given changes in schedule and scope, affords several opportunities for improvement. Cost and performance models must be complemented by econometric measures. These measurements help to generalize more specialized models and test their hypotheses. In general, these actions enable the creation of an empirical database that may illustrate the benefits that supply-chain strategies can provide. The study determined that supply chain management has the following effects on the construction sector:

• Cost and performance modeling of subcontractor and supplier production.
• Enhanced scheduling techniques, especially concerning the arrangement and positioning of buffers to mitigate uncertainty and adapt to changes.
• Improved subcontractor coordination methods by linking site production to resource management.
• Improved accounting and production control systems.

The case study's findings indicate time and money savings. The favorable attitude among the partners toward sharing their expertise and experiences on future initiatives must be maintained in order to maintain the momentum of these gains. By using this strategy, the client and end users will receive additional benefits.

The planning of a construction project must include the process of risk management. Project managers use their own experience and knowledge to take the necessary actions when a risky event occurs while a project is being carried out. Although past project knowledge and expertise can be very helpful in detecting and managing risks in a new project, such knowledge typically sits in project managers' heads and is rarely recorded in a reusable form of information.

Managers can be helped by a decision support system that has a case-base of prior actions done and a record of prior risk management plans when managing the risk of construction supply chains in a new project. This research introduces a model for a decision support system designed to aid decision-makers in the construction sector with supply chain risk management. The system utilizes a case-based reasoning approach and is capable of supporting decisions pertaining to both proactive and reactive strategies in managing supply chain risks.

1.2. Aims and Objectives

The primary objective of current research is to measure the effectiveness of integrated software platforms in the management of the supply chain in the construction industry and examine their effectiveness in managing projects. Instead of investigating the effectiveness on the scale of the whole firm, we narrow down our study to the project level. This approach would take into account each individual project and, by avoiding aggregate performance measurement, reveal valuable information on how each project may benefit from or even be impaired by utilizing integrated software solutions for supply chain management.

The research problem for this topic is to understand the influence and implications of integrated supply chain platforms on project management criteria in the context of construction projects across Germany. Among the criteria of project management, we focus on time, cost, and risk management as the parts that could be influenced by the implementation of the integrated software platforms. Mainly, the construction industry is the focus of current research to avoid any unconformities among different industries that might bias the results. By using a survey, the validity of the proposed model would be examined, as would the degree of influence of software utilization on different aspects of project management within the construction industry.

1.3. Research questions

Based on the research problem, the following objectives can be formulated:

Research question 1:

How does the adoption of integrated supply chain platforms (ISCP) in construction projects affect overall project performance and success rate?

Research question 2:

What are the specific time management benefits that construction projects gain when using ISCP compared to conventional supply chain techniques?

Research question 3:

In what ways do construction projects that use ISCP demonstrate more efficient cost management compared to projects that rely on traditional supply chain management techniques?

Research question 4:

How do construction projects that use ISCP demonstrate better risk management compared to projects that rely on traditional supply chain management methods?

Research question 5:

What are the changes in the results of using ISCP in time, cost, and risk management in construction projects in different European countries?

Research question 6:

How do construction project managers perceive the impact of ISCPs on time, cost, and risk management, and what are their experiences of implementing and using such platforms?

1.4 Research scope and methodology

The research is limited to the construction industry in European countries, with a main focus on the German market. Also, the research is limited to the use of integrated software platforms in supply chain management. To get more detailed answers, we focused our research on the projects and not the overall firm outcomes.

Our research is based on a survey that has been conducted aimed at project managers within the construction industry in Germany, and the effect of the integrated software platforms on time, cost, and risk management within projects in this industry has been analyzed.

In order to analyze the survey results,. The Structural Equation Model (SEM) was used to check the data and perform statistical evaluations on it. (number of samples, limitations in the sampling and work, etc. It must be briefly stated here, and with further exploration of the SEM and statistical works done on the project, we can add more items to this part)

Research Scope

This section defines the boundaries and extent of the research, outlining the specific areas and aspects covered by the study. The research scope of this study encompasses:

Geographical Scope

The study focuses on the German construction industry as the primary geographical area of interest. It includes various regions within Germany, with a particular emphasis on urban and industrial centers.

Construction Industry Focus

The research is focused exclusively on the construction industry, specifically examining the utilization and impact of integrated supply chain platforms within this sector. It encompasses a wide range of construction project types prevalent in Germany, including commercial, residential, infrastructure, and industrial projects.

Participants

The study involves active participants within the German construction industry, including construction professionals, project managers, and representatives from construction firms. These participants possess firsthand experience with the adoption and implementation of integrated supply chain platforms, offering valuable insights from diverse backgrounds and roles within the construction sector.

Integrated Supply Chain Platform Aspects

The research explores various aspects of integrated supply chain platforms, emphasizing their adoption processes, critical success factors, benefits, and key performance indicators within the construction industry. It investigates how these platforms facilitate efficient time, cost, and risk management, along with their impact on project performance and outcomes.

Timeframe

The study considers the implementation of integrated supply chain platforms and their effects on project performance over a specific timeframe within the German construction industry. This timeframe enables the analysis of historical trends and recent developments, providing valuable insights into the evolution of supply chain management practices within construction projects.

Limitations

While the primary focus of the study is on the German construction industry, it acknowledges potential limitations in terms of generalizability to other regions and industries. The research does not extend to an extensive exploration of integrated supply chain platforms in other European countries or global contexts, maintaining a targeted focus on the German construction sector.

1.5 The Structure of the Thesis

Overall, the thesis undertakes a comprehensive examination of how integrated supply chain platforms impact project management criteria in the construction industry, with a specific focus on German construction projects. It begins by establishing the research objectives, questions, and methodology in the introductory chapter, providing readers with a clear roadmap for navigating the subsequent chapters. Following this, a thorough literature review chapter synthesizes existing knowledge identifies gaps, and sets the stage for contributing new insights.

The methodology chapter outlines the research approach, including data collection, sampling methods, and model development. It ensures transparency and rigor in the research process, laying the foundation for the empirical analysis presented in later chapters. The results chapter presents empirical findings derived from a survey of construction industry practitioners, complemented by statistical analysis and comparison with existing literature, enhancing the clarity and accessibility of the findings.

In the discussion chapter, the results are interpreted within the theoretical framework established in the literature review, offering insights into the implications for construction project management and acknowledging study limitations. Additionally, recommendations for future research directions foster a holistic understanding of the findings. The concluding chapter synthesizes key findings, underscores practical implications, and reflects on the significance of the research, providing closure to the thesis journey.

The research methodology employs Structural Equation Modeling (SEM) to analyze the data collected, aiming to discern the influence of integrated supply chain platforms on project management criteria. Key variables representing both platform adoption and project management outcomes are identified, with a questionnaire designed to solicit insights from industry practitioners. The subsequent analysis involves developing an SEM model, testing hypothesized relationships, and assessing model fit, ultimately providing valuable insights for academia and industry practitioners alike.

Chapter 2

Literature Review

2.1 Definition and Concepts

2.1.1 Supply chain management

Supply chain management, a term that emerged in the late 1980s and gained widespread adoption in the 1990s, refers to the strategic coordination of production, inventory, logistics, and transportation activities among supply chain participants. The goal is to achieve the optimal balance of market responsiveness and operational efficiency (Hugos, 2018)[23]. In essence, it represents a collaborative effort involving individuals and companies operating within a network of interconnected processes (Tommelein et al., 2003)[24].

Krajewski, Ritzman, and Malhotra (2007) describe supply chain management as "the planning, organization, control, and motivation of resources engaged in the movement of services and materials throughout the supply chain." Furthermore, This collaboration takes into consideration a range of factors, encompassing aspects like geography, customer base, products, and financial reporting(bolstorff and Rosenbaum in their 2012 publication)

SCM (supply chain management) is the integration of trade partners' core business processes from initial raw material extraction to final or end customer, encompassing all intermediate processing, transportation, and storage activities. er, Tan, and Leong (2012)[25]

This comprehensive approach to supply chain management emphasizes the importance of coordinating and optimizing various activities across the entire supply chain to enhance efficiency and meet market demands.

2.1.2 Integrated Supply Chain Platform (ISCP)

An Integrated Supply Chain Platform is a defined process in which suppliers, partners, and customers operate within a common market space and work together to strategically coordinate, execute, and oversee the seamless flow of information, services, and products throughout the entire supply chain (Mathegu, 2017; Lambert & Cooper, 2000).[26]

The objective of this integration is to improve business operations in terms of speed, agility, real-time control, and customer response [27]. This platform integrates and streamlines the flow of data, materials, and resources across different stages of the supply chain, thereby facilitating real-time coordination, transparency, and efficiency [28]While this platform offers various tools to support supply chain collaboration, it also presents challenges in terms of obstructing integration with business partners. ISCP focuses on inventory management within supply chain coordination, leveraging quantitative modeling and organizational insights to optimize ordering and logistic policies, ultimately reducing supply chain costs and promoting cooperation among partners [29]

2.1.3 Supply Chain Software Solutions

Within the realm of supply chain management, various software solutions are available to manage and optimize the material supply chain. These solutions play a crucial role in streamlining operations, improving efficiency, reducing costs, and enhancing overall supply chain management. The coordination between supply chain planning and execution processes must be seamless, ensuring tight integration not only between each other but also with the existing ERP systems in placeThe supply chain planning processes typically need transaction histories, budgets, and financial plan data from the ERP system to establish the decision parameters. Enterprise Supply Chain Management Integrating Best-in-Class Processes VIVEKSEHGAL2009 Published by John Wiley&Sons, Inc.Hoboken, NewJersey.

2.1.4 Project Management Criteria

Project management criteria encompass the essential elements of knowledge, skills, tools, and techniques employed in the orchestration of project activities to fulfill project objectives. Project management involves the direction of project endeavors to produce desired results. Project teams can employ diverse methodologies, such as predictive, hybrid, or adaptive, to attain these objectives [30]

Project management criteria are standards, factors, or criteria that are used to evaluate the success of a construction project, according to the PMBOK definition. They include parameters such as project scope, quality, schedule adherence, budget control, stakeholder satisfaction, and overall project performance. In this article, we will specifically examine the impact of an integrated supply chain platform on three important aspects: budget control, time management, and risk management[31].

The research by Xinyu Wei, Victor Prybutok, and Brian Sauser explores key antecedents for successful SCM integration in project-based environments (Wei et al.)[32]. The research divides these elements into four categories: integration of information technology (IT), coordination within the organization, management of risks, and the resilience and complexity of the supply chain. (Wei et al.)[25]. It provides a systemic diagram visually representing the SCM strategy adoption pathway**.** The study emphasizes the need for increased focus on SCM among project teams to enhance projects (Wei et al.)[33]. This research highlights the significance of integrating supply chain management principles within project-based environments, shedding light on the factors contributing to successful SCM implementation in projects.

2.1.5 Time Management

Time management in construction projects involves the efficient allocation and utilization of time resources to ensure that project activities are completed within specified deadlines. It encompasses project scheduling, task sequencing, resource allocation, progress tracking, and schedule optimization. The success of the project highly depends on the appropriate implementation of time management procedures within the project team.

Time management, within the PMBOK framework, is mentioned as a crucial aspect of effective project management. It encompasses processes and activities aimed at ensuring a project's completion within the scheduled timeframe. This involves planning how the schedule will be created, defining tasks, sequencing activities, estimating durations, developing a detailed timeline, and controlling the schedule throughout the project. Effective time management in PMBOK ensures projects are on track, avoiding delays and disruptions, and is essential for successful project execution[31].

As per Jason Westland's (2006) perspective, time management involves monitoring and regulating the duration that employees dedicate to a project.Max Wideman (1990) offers a broader definition, stating that time management is the function required to maintain an appropriate allocation of time to the overall conduct of the project through its successive stages of the natural life-cycle (i.e., concept, development, execution, and finishing). This is achieved through processes such as time planning, time estimation, time scheduling, and schedule control[34].

In essence, time management is all about planning and controlling time throughout all stages of the project, and it plays a vital role in construction project management.

2.1.6 Cost Management

Cost management revolves around strategic planning, meticulous control, and vigilant monitoring of project expenditures. This encompasses a spectrum of activities, including cost estimation, budget formulation, real-time expense tracking, variance analysis, and the execution of measures to exercise command over costs.

This systematic approach ensures that projects remain faithful to the endorsed budget, curtails the risk of cost overruns, and optimizes the allocation of resources to achieve peak cost effectiveness.

Aligned with the guidelines set forth in the Project Management Body of Knowledge (PMBOK) 7th edition, the project budget materializes from the consensus-based appraisals delineated for the project[35]. The insights delineated pertaining to estimation are seamlessly applied to the panorama of project costs, thus giving rise to a panoramic vista of cost estimates. The aggregation of these estimates takes the form of the cost baseline, a foundational cornerstone in project fiscal management. This bedrock of cost data is frequently apportioned across the tapestry of the project timeline, ingeniously mirroring the moments when these financial outlays will come to fruition. This strategic maneuver equips project managers with the ability to harmonize the fiscal resources allocated within a stipulated budgetary span with the choreographed cadence of project tasks.

If fiscal constraints encircle a specific budget phase, a nuanced coordination of work rescheduling can be strategically orchestrated to harmonize in sync with these financial limitations.

Cost management revolves around the strategic planning, meticulous control, and attentive monitoring of project expenditures. This systematic approach ensures that projects remain faithful to the endorsed budget, curtails the risk of cost overruns, and optimizes the allocation of resources to achieve peak cost effectiveness. Project Cost Management – Global Issues and Challenges Dr. Peter Smitha (2014)

2.1.7 Risk Management

Risk management in construction projects involves identifying, assessing, and managing potential risks and uncertainties that may impact project objectives. The construction process of a construction project is actually a process full of uncertainty and risk. Effective risk control will be one of the key elements for the success of construction project management, especially considering the long duration, involvement of many participating units, and complex environmental impacts. Any one of the activities or changes in any party involved in the project construction can affect the activities of the relevant parties.

Risk management in PMBOK is defined as a systematic process of identifying, analyzing, and responding to project risks to ensure project success. It involves assessing risks, developing strategies to mitigate or exploit them, and continuous monitoring and control throughout the project[31].

Risk management encompasses activities such as risk identification, risk analysis, risk mitigation planning, and risk monitoring. By effectively implementing risk management practices, construction projects can minimize the likelihood and impact of potential risks, ensuring project success and reducing the possibility of unexpected events or disruptions[36].

2.1.8 Construction Projects

In both developed and developing countries, the construction industry can be defined as the sector of the economy that, through planning, design, construction, maintenance and repair, and operation, transforms various resources into constructed facilities ranging from residential to nonresidential facilities that play critical roles in the development process.Civil engineering projects, such as transportation infrastructure, power projects, irrigation, drainage, and water supply, may account for up to half of overall building production in developing countries. Housing accounts for less than a third of the overall output, with the remainder going toward the development of schools, factories, offices, hotels, and hospitals, among other items (Wells, 1986). Owners, architects, engineers, quantity surveyors, project managers, construction project managers, and general contractors include special trade subcontractors, domestic subcontractors, selected subcontractors, and all other project participants such as laborers, plant operators, and the like.

The construction sector is recognized as a crucial participant due to the vast range of economic and social demands it meets, as well as the considerable contribution it contributes to the achievement of several main national goals. In essence, it is a service industry that obtains its inputs and outputs from sources outside its sector, with which it is frequently and complexly interrelated (Salleh, 2009; Moavenzadeh & Rossow, 1975). The development of the construction industry is an essential engine that supports growth because it contributes significantly to GDP, and its capacity and effectiveness to meet the demand of the national economy for physical infrastructure is an indicator of economic performance (Tanzanian Construction Policy, n.d.).

The importance of building is derived from its contribution to national employment and the development of built infrastructure, both of which are essential to a nation's development.

2.2 The Theoretical Foundations

2.2.1 Integrated Supply Chain Platform Adoption (ISCPA) and Time Management (TM)

In the study by Cornelia Droge, ISCPA's impact on Time Management (TM) is evident. ISCPA, encompassing both external strategic design integration and internal design-process integration practices, significantly enhances time-based performance.

Integrated Supply Chain Platform Adoption (ISCPA) is intrinsically linked to Time Management (TM) in construction projects. Drawing from the insights of Mandičák et al. (2021)[37], it is evident that supply chain platforms in construction leverage big data and technology to streamline operations, ultimately influencing project timelines positively. As elucidated by Hatmoko (2006), these platforms wield significant influence by mitigating delays. Without them, supply chain issues can cause median delays of up to 67 days, equivalent to a staggering 22% of the project's duration. The primary culprits include material flow, labor allocation, and information dissemination. Particularly noteworthy is that sourcing materials alone can result in a median delay of 14 days, equivalent to 5% of the project's duration[38]. However, Hatmoko's findings emphasize that leveraging supply chain platforms to facilitate subcontracting can lead to a remarkable 45% reduction in median delays, underscoring their pivotal role in enhancing project efficiency. Thus, the adoption of integrated supply chain platforms contributes significantly to effective time management in construction projects.

2.2.2 Integrated Supply Chain Platform Adoption (ISCPA) and Cost Management (CM)

According to Peter Kelle's article, "The role of ERP tools in supply chain information sharing, cooperation, and cost optimization," Integrated Supply Chain Platform Adoption (ISCPA) emerges as a pivotal element for cost management within supply chains. ISCPA, an integral aspect of ERP systems, facilitates efficient data exchange among supply chain partners, enabling them to minimize overall supply chain costs. The article highlights the potential for cost optimization through ISCPA and offers quantitative insights[29].

The nexus between Integrated Supply Chain Platform Adoption (ISCPA) and Cost Management (CM) within construction projects is of paramount importance. As established by Mandičák et al. (2021)[37], supply chain platforms in construction leverage big data and technology to streamline operations, ultimately contributing to cost minimization. Furthermore, Hatmoko's research (2006) highlights that these platforms play a significant role in mitigating delays, which, in turn, impact costs[38]. Without supply chain platforms, projects can experience substantial delays, equivalent to a significant portion of the project's duration. Material flow, labor allocation, and information dissemination emerge as critical cost drivers. Particularly striking is that difficulties in sourcing materials alone can result in cost escalations of 5% of the project's budget. However, Hatmoko underscores that harnessing supply chain platforms to facilitate subcontracting can lead to substantial cost reductions. These findings emphasize the positive relationship between ISCPA and CM, affirming that integrated supply chain platforms are instrumental in optimizing cost management in construction projects.

2.2.3 Integrated Supply Chain Platform Adoption (ISCPA) and Risk Management (RM)

The relationship between Integrated Supply Chain Platform Adoption (ISCPA) and Risk Management (RM) in construction projects is a crucial aspect of project success. Mandičák et al[37]. (2021) highlight that supply chain platforms in construction, enriched by big data and technology, enhance project management integrity, ultimately mitigating risks. Concurrently, Hatmoko's research (2006) underscores that these platforms significantly impact project efficiency by reducing delays, a factor intricately linked to risk management[38]. Delays can trigger an array of risks, from cost overruns to contractual disputes. Thus, the adoption of integrated supply chain platforms enhances risk management by providing real-time visibility into the supply chain, enabling proactive risk mitigation measures, and ensuring smoother project execution. In essence, ISCPA contributes positively to risk management, enhancing the resilience and overall success of construction projects.

In the study titled "Enhancing Risk Management in a Changing World: The Impact of Integrated Supply Chain Platforms," Agustina Calatayud underscores the importance of a connected supply chain and its significant impact on the smooth and continuous flow of materials, information, and finances. Calatayud identifies two primary drivers of this connectivity: information systems and physical infrastructure. The connectivity of information systems facilitates real-time risk detection, prevention, and swift responses, thanks to emerging digital technologies such as IoT, blockchain, and AI. Likewise, physical connectivity, dependent on infrastructure and logistics, is crucial for minimizing delays and disruptions.

2.3 Gaps in the existing literatures

Based on previous studies and literature, several notable gaps in the existing literature related to Integrated Supply Chain Platforms (ISCPs) and their impact on European construction project management are identified:

Comprehensive Studies:

Existing literature lacks comprehensive studies specifically focused on the impact of ISCPs on project management criteria (time, cost, and risk management) in construction projects across European countries. Previous research often examines isolated aspects of supply chain or project management, neglecting the holistic impact of ISCPs.

Limited Empirical Studies:

More empirical research is needed to analyze real-world implementations of ISCPs in construction projects. Empirical studies can provide valuable insights into the actual effectiveness of ISCPs and their influence on project outcomes in diverse European contexts.

Comparative Studies:

Few studies compare different supply chain software solutions or ISCPs, in terms of their impact on project management criteria. By directly comparing the effectiveness of various ISCPs, researchers and industry professionals can better understand which platforms are most suitable for specific project types or contexts.

Risk Management:

More research is needed to explore how ISCPs specifically impact risk management in construction projects, including enhancing risk identification, analysis, and mitigation strategies.

This study aims to address these gaps in the existing literature by focusing on the impact of ISCPs on project management criteria in European construction projects. Through empirical insights and consideration of the European context, including risk management implications, this research seeks to enrich the understanding of ISCPs' influence on construction project management practices in Europe.

Chapter 3
Research Methodology

In this chapter, we review existing research methods and adopt the one that best suits our current research. Later, we will discuss the steps that we have taken to use the selected method in our research.

3.1 Research methods overview

Collis and Hussy argue that research can be divided into four categories: rationale, process, purpose, and outcome. If the research is shifting from specific to general or vice versa, it will be expressed in the rationale. The research can be categorized as either inductive or deductive under this heading. The second category is the procedure, which describes the procedure for gathering and analyzing data[39]. The research can be categorized as either qualitative or quantitative under this heading. The purpose, or rationale for undertaking the research, is the third category. Those classifications include analytical, descriptive, predictive, and exploratory. The fourth category, research outcome, indicates whether a study is aiming to further knowledge or address a particular issue.[8]

Explanatory or analytical research extends descriptive research by seeking to explain phenomena through measurement and comprehension of their interconnections. This method of analysis expounds on and delineates the reasons and mechanisms underlying various occurrences. In this category, the most fitting questions are "why" and "how."

Descriptive research endeavors to discern and categorize distinctive details pertaining to a specific matter or concern. This type of study aims to identify events in their natural state. The following questions are appropriate: "where," "how much," "how many," "what," or "who."

The goal of predictive research is to make the use of information from analysis simpler by anticipating a particular phenomenon based on a hypothesis. In other words, the goal of this kind is to calculate the likelihood of an event. Queries such as "where," "what," "who," "how many," and "how much" are suitable for the context.

Exploratory research looks for theories, concepts, or patterns. When there are only a few studies to refer to, this research is used. What are the right questions to ask for this type of research? Why? How? How much? How often? Where?

3.1.1 Quantitative and qualitative research

Research can be divided into qualitative and quantitative categories, depending on the methodology. According to Creswell (2009), quantitative data is an approach to research where the researcher uses positivist claims to: develop knowledge based on prior investigation, which can be seen in particular in (i.e., use of observation and measurement, cause and effect thinking, test of theories, reduction to specific variables, and hypothesis with questions), employ investigation strategies and inquiry (i.e., surveys and experiments), and also collect data on preexisting conditions. With the use of numerical data collection, analysis, and testing, this kind of research aims to comprehend a certain phenomenon [40]. This strategy is deductive, which may be better suited for mature or specialized study fields.

Along with the ideas already discussed, Creswell (2009) also contributed a mixed approach. This technique of inquiry is "where the researcher is inclined to base claims of knowledge on practical ground (e.g., problem-centered, consequences-oriented),) according to the definition given by the author[40]. The mixed approach allows for techniques for study that call for collecting data sequentially or concurrently and using numbers paired with text-based information in order to have a better knowledge of the research problem. A more thorough explanation of these three strategies may be found in Table 1.1

Aspect	Qualitative Approach	Quantitative Approach	Mixed Method Approach
Philosophical assumption	· Deductive knowledge · Corroborative knowledge claims · Conducive knowledge claims	Post-positivist knowledge claims	Programmatic knowledge claims
Strategies of inquiries	· Phenomenology · Ethnography · Grounded Theory · Narrative Case	· Experimental · Surveys	· Concurrent · Sequential · Transformative

	· Study		
Methods	· Emerging Approaches · open-ended questions · Textual or Image data	· Predetermined methodologies · Closed-ended questioning · Numerical data analysis	· Both open and closed-ended questions ·Both qualitative and quantitative approaches · Both emerging and predetermined
Practice of research	Gather participants' answers Positions herself or himself Highlights the single concepts or phenomena Brings personal value into the study Studies the context or settings of participants Test the accuracy of findings Creation an agenda for changes Cooperation with participants Extract the constructive meaning from the data	· Test the validity of the theories · Identify the variables elements for the study ·Link those variables with the questions and hypothesis ·Use standards of reliability and validity · Measure and observe the information numerically · Use impartial approaches · Uses statistical procedures	· Gathers both qualitative and quantitative data · Develops an explanation for mixing · Integrates the data at different stages of inquiry · Presents visual pictures of the process in the study ·Employs the practices of both quantitative and qualitative research

Table 3.1 Mixed method, quantitative and qualitative research approaches

3.1.2 Inductive or deductive research

Deductive or inductive research might be used to describe the study. According to Collis and Hussy (2013), deductive research is a study in which a theoretical and conceptual framework is created and verified by experimental observations, and then specific examples are drawn from generalizations, moving from the general to the specific[39]. Inductive research, in contrast, moves from the specific to the general based on observations of experimental reality

Research type	Classification base
Inductive or deductive research	Logic of the research
Qualitative or quantitative research	Process of the research
Analytical, descriptive, predictive or exploratory research	Purpose of the research
Basic or applied research	Research outcome

Table 3.2 Research main classifications (Collis and Hussey, 2013)

3.2 Research Approach and Strategy

The systematic empirical exploration of quantitative qualities, phenomena, and their interactions is referred to as quantitative research. According to Mouton (1983), referenced by Brynard et al. (2014) and Anonymous (n. d.), it is related to analytical study and aims to reach a universal conclusion[41].

Quantitative research is based on generating research hypotheses and empirically testing them on a particular set of data because it is deductive and particularistic in character (Frankfort-Nachmias & Nachmias, 1992). Its goal is to create and apply mathematical theories, models, and hypotheses related to the phenomenon.

Additionally, it tests variables on a sample of people and expresses the link between variables using effect statistics like correlations, relative frequencies, or variations between means: its emphasis is mostly on testing theory. The quantitative research method, which applies techniques from the physical sciences to ensure objectivity, generalizability, and reliability, is thought to be appropriate in situations where it is possible to measure the variables of interest, form and test hypotheses, and draw conclusions from samples of the population (Liebscher, 1998; Weinreich, 2006)[42]. Data is created by counting and measuring things or objects.

In quantitative research methodology, the researcher is regarded as being external to the actual research, and regardless of who does the research study, the results are assumed to be replicable. The ability of this paradigm's approaches to generate accurate and quantitative data and their generalizability to a larger population are some of its strengths. In order to assure impartiality, generalizability, and reliability, quantitative research employs techniques adapted from the physical sciences, according to Weinreinch (2006)[42].

In order to ascertain the perception of ISCPs in the construction industry, the advantages of implementing an ERP system in a construction firm, the key impacts on project management criteria, time, cost, and risk, as well as the overall performance of the project, the study adopted a quantitative research approach. It also sought to ascertain whether the outcome of the ISCPs could differ if they were used by different companies in different European countries.

Experiments and surveys are required in quantitative research to characterize and explain the phenomenon being studied. According to Hittleman and Simon (1997), quantitative research uses methods like quantitative analysis and questionnaires, initial investigation, observations, and experiments to collect data that is revised and tabulated in numbers, allowing the data to be characterized by the use of statistical analysis. Based on this, the researchers disseminated a questionnaire survey to participants in the current study in order to collect primary data, which served as the major data used for the analysis. The following criteria for choosing this approach to gathering primary data were endorsed by Kealey and Protheroe (1992) and De Vos et al. (2004)[43], [44]:

- Gives an account of characteristics with precision;
- Covers large portions of the sample population in relatively short periods of time;
- Minimizes or eliminates subjectivity of judgment; and
- Uses a standardized research design according to a fixed procedure that can be replicated.

3.2.1 Targeted Population

Kothari (2004) states that all items in any field of inquiry constitute a “universe” or "population.”. For purposes of sampling, a population does not refer to the population of a country but to objects, subjects, phenomena, cases, and events that the researcher wishes to research in order to establish new knowledge (Brynard et al., 2014)[41]. A population refers to a group in the universe that possesses specific characteristics the universe being all subjects who possess the attribute in which the researcher is interested, e.g., the total number of inhabitants in the country who possess a post-graduate qualification.

The targeted respondents that made up the population that was sampled for this study were mainly project managers or other managers such as construction managers, construction project managers, logistics managers, civil engineers, and other professionals who are involved in construction projects in European countries, namely Germany. The list of companies was taken from the internet directories that contained firms that are active in different sectors of the construction industry, from suppliers to consultants and developers. In order to have the maximum inclusion, no preliminary screening based on the size of the firm or the value of the projects that they perform was made.

3.3 Model Development

In the process of developing the model for this study, several key parameters were considered; each represents a critical aspect of the research and contributes to the overall understanding of integrated supply chain platform adoption (ISCPA) in the context of time management (TM), cost management (CM), and risk management (RM) within construction projects. Based on these parameters and their interactions and relations, we define our variables and build our model, and then we check if the data supports our model or not.

3.3.1 Integrated Supply Chain Platform Adoption

This subsection delves into the concept of Integrated Supply Chain Platform Adoption (ISCPA). It explores the extent to which construction firms adopt and integrate digital supply chain platforms into their project management processes. ISCPA is reflected through indicators that consider factors like technology adoption, information sharing, collaboration, visibility, and transparency.

3.3.2 Time Management

Time Management (TM) is a primary focus within this study. It assesses the efficiency and effectiveness of project scheduling, project delays, and overall project time performance within construction projects. TM is evaluated based on various time-related metrics and indicators, including project duration, critical path analysis, schedule adherence, and time-related deviations.

3.3.3 Cost Management

Cost Management (CM) represents another critical dimension. It assesses financial control and expenditure monitoring within construction projects. CM evaluates how well construction firms manage total project costs, avoid cost overruns, control expenses, and adhere to budgetary constraints. This construct encompasses factors such as cost estimation accuracy, cost tracking, cost overruns, and financial control mechanisms.

3.3.4 Risk Management

Risk Management (RM) is the third major focus, centered on the identification, assessment, mitigation, and response to risks within construction projects. RM can be measured through Risk Exposure (a measure of potential project risks) and Risk Mitigation Effectiveness (the effectiveness of risk management strategies implemented during the project).

3.3.5 Hypothesized Relationships

In this section, we delve into the intricacies of the hypothesized relationships among our core constructs: Integrated Supply Chain Platform Adoption (ISCPA), Time Management (TM), Cost Management (CM), and Risk Management (RM). Additionally, we introduce the concept of covariance and its vital role in quantifying the associations between these constructs.

- **Hypothesized Relationships**

ISCPA and TM: according to Cornelia Droge, Mandičák et al., and Hatmoko, a higher level of Integrated Supply Chain Platform Adoption (ISCPA) will positively influence Time Management (TM) within construction projects. This hypothesis implies a positive linear relationship between these two variables, where an increase in ISCPA corresponds to an increase in effective Time Management[37], [38].

ISCPA and CM: The studies of Kelle, et al., and Hatmoko shows that a greater degree of ISCPA will positively affect Cost Management (CM). In line with this, a positive covariance is anticipated, indicating that as ISCPA increases, Cost Management also tends to increase[38], [45].

ISCPA and RM: Our hypothesis asserts that based on Mandičák et al. and Hatomo studies, there exists a positive relationship between ISCPA and Risk Management (RM)[37]. This positive covariance signifies that heightened levels of ISCPA align with improved Risk Management practices within construction projects.

Given the oveall abovementioned effects of ISPCs on different aspects of construction projects, i.e., time, cost, and risk, it is acceptable to state that ISPC adoption will positively impact the overall project performance in the construction industry.

TM and CM: Effective Time Management (TM) is expected to have a positive influence on Cost Management (CM). This implies a positive covariance, indicating that proficient Time Management corresponds to better Cost Management practices.

TM and Overall Performance: is expected that effective Time Management (TM) will positively impact the overall project performance in the construction industry.

CM and Overall Performance: Cost Management (CM) and Overall Performance: are intertwined. Proficient Cost Management is anticipated to have a positive impact on Overall Performance. This implies a positive covariance, signifying that as CM improves, so does the Overall Performance of the construction industry.

Hypothes	Relationship	Interpretation
H1	ISCPA⇒ CM	ISCPA positively influences Cost Management (CM).
H2	ISCPA⇒ RM	ISCPA positively influences Risk Management (RM).
H3	ISCPA⇒ TM	ISCPA positively affects Time Management (TM).
H4	TM ⇒ CM	Effective Time Management positively affects Cost Management (CM).
H5	TM ⇒ Performance	Time Management positively influences Overall Project Performance
H6	CM ⇒ Performance	Proficient Cost Management positively affects Overall Project Performance

Table 4.1 Hypothesized Relationships

3.3.6 Variables and Relationships

3.3.6.1 Independent variable

Integrated Supply Chain Platform Adoption (ISCPA)

The concept of Integrated Supply Chain Platform Adoption (ISCPA) encapsulates the extent to which construction firms adopt and integrate digital supply chain platforms into their project management processes. ISCPA is reflected through a set of indicators that consider factors like technology adoption, information sharing, collaboration, visibility, and transparency.

3.3.6.2 Dependent variables

- **Time Management (TM)**

Time Management (TM) is the primary dependent variable in this study, focusing on the efficiency and effectiveness of project scheduling, project delays, and overall project time performance within construction projects. TM is evaluated based on various time-related metrics and indicators, including project duration, critical path analysis, schedule adherence, and time-related deviations.

- **Cost Management (CM)**

Another important dependent variable in the current study is the Cost Management (CM), which represents financial control and expenditure monitoring within construction projects. This construct assesses how well construction firms manage total project costs, avoid cost overruns, control expenses, and adhere to budgetary constraints. CM encompasses factors such as cost estimation accuracy, cost tracking, cost overruns, and financial control mechanisms.

- **Risk Management (RM)**

Risk Management (RM) is the third dependent variable, focusing on the identification, assessment, mitigation, and response to risks within construction projects. RM can be measured by risk exposure, a measure of the potential risks associated with the project, and risk mitigation effectiveness, the effectiveness of risk management strategies implemented during the project.

3.3.6.3 Control Variables

To isolate the effect of ISCP adaptation, it is desired to include control variables that could also influence cost, time, and risk management in construction projects. Control variables are typically included in SEM to control for potential confounding factors or to explore moderation effects. In the current study, these could include:

- **Project Size:** The scale and complexity of the construction project since implementation of ISCP might result in different complexity and size of the projects
- **Experience of Project Team:** The level of experience and expertise of the project management and construction teams.

3.4 Ensuring Validity and Reliability

3.4.1 Statistical Conclusion Validity (SCV)

Statistical Conclusion Validity (SCV) holds a central position within our research endeavors, serving as a critical determinant of accuracy and the derivation of meaningful conclusions from our meticulous data collection and analysis. To fortify the reliability of our findings, we employ a diverse array of statistical methods, including regression analysis and hypothesis testing, which form the foundation of our study.

In the realm of educational research, the overarching significance of validity is incontestable. As articulated by Muijh (2004)[46], validity is the linchpin governing the design and application of measurement instruments, ensuring that the tests we utilize faithfully gauge the constructs they are intended to represent. Furthermore, echoing Latif's insights (2011), valid outcomes obtained through assessments faithfully mirror the true skills and attributes under scrutiny. These observations underscore the profound impact of validity within the sphere of educational research, where the integrity of our findings is pivotal to our comprehension and evaluation of learning and performance.

3.4.2 Appropriate Statistical Methods

The selection of appropriate statistical methods is paramount to aligning with our research questions. Nayak BK, Hazra A. How do I choose the right statistical test.? Indian J Ophthalmol. indicates that to select the appropriate statistical method, one needs to know the assumptions and conditions of the statistical methods so that a proper statistical method can be selected for data analysis.

Careful consideration has been given to the statistical techniques that best suit the nature of our data and the specific inquiries we aim to address. These methods encompass regression analysis, hypothesis testing, and other relevant statistical tools chosen to ensure that our analyses closely align with our research objectives.

3.4.3 Ensuring the Robustness of Statistical Conclusion

3.4.3.1 Validity in Research

- **Statistical Conclusion Validity (SCV)**

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3.4.3.2 Ensuring the Robustness of Statistical Conclusion Validity in Research

"In this study, we adhere to a set of fundamental principles to ensure the statistical conclusion validity (SCV) of our findings. Central to this endeavor is our commitment to data quality, where rigorous cleaning and validation procedures are employed to eliminate outliers, missing values, and inaccuracies, reinforcing the reliability and validity of our dataset. Furthermore, we emphasize the determination of an appropriate sample size, and conduct power analyses to fortify the robustness of our statistical analyses and enhance the generalizability of our results. We meticulously balance statistical power with resource constraints, making informed decisions about sample size that contribute significantly to the strength and credibility of our conclusions.

Hypothesis testing is a foundational element in our research methodology, driven by well-defined, pre-planned hypotheses that guide our statistical analyses. We meticulously select and outline the appropriate statistical tests in alignment with our research objectives, facilitating objective evaluation. We interpret our results diligently, considering effect sizes alongside p-values to gauge the real-world significance of our findings. The possibility of replication and peer review is also actively considered to bolster the robustness of our conclusions, and our commitment to transparency is unwavering, with clear documentation of statistical procedures and results. By rigorously adhering to these principles and practices, we ensure that our research's SCV remains unassailable, producing findings that are robust, credible, and reliable.

3.4.3.3 Internal Validity

- **Instrument Validity**

Instrument validity stands as a pivotal determinant in affirming the trustworthiness of our questionnaire as a measure of the constructs under investigation. Our rigorous validation process encompasses various tests, including content validity, construct validity, and criterion-related validity, all aimed at ensuring the questionnaire's reliability and validity.

- **Content Validity**

Content validity is a foundational element of our research methodology, serving to guarantee that the questions within our questionnaire not only exhibit clarity and comprehensibility but also directly pertain to our research objectives. To rigorously assess the content validity of our questionnaire, we meticulously followed these steps:

1. Convening an Expert Panel: An expert panel, comprising professionals with substantial expertise in the fields of construction project management and supply chain platforms, was convened. Their specialized knowledge was harnessed for a thorough evaluation of our questionnaire.

2. Evaluation of Multiple Dimensions: The expert panel conducted a comprehensive assessment of the questionnaire from various dimensions to gauge its content validity in alignment with our research objectives. Specifically, they deliberated on the following aspects:

A. **Clarity**: The language used in the questions was carefully scrutinized to ensure clarity and comprehensibility, to eliminate ambiguities or confusing language that might hinder respondents' understanding.
B. **Relevance**: The expert panel meticulously assessed whether each question had a direct bearing on our research objectives, thus ensuring that the questions centered on topics of genuine significance to our study.
C. **Comprehensiveness**: The panel also considered the questionnaire's comprehensiveness, seeking to identify any significant topics or variables that may have been inadvertently omitted.

3. Rating System: To systematize the assessment process, a rating system was implemented for each questionnaire item. Expert panel members were tasked with rating each item's necessity as "necessary," "useful but not necessary," or "unnecessary." Additionally, they provided ratings for each item's relevance, ranging from "completely relevant" to "not relevant."

This rigorous evaluation process enabled us to refine the questionnaire, ensuring its seamless alignment with the focus and objectives of our research. By incorporating expert feedback, we elevated the content validity of our research instrument, thus fortifying the quality and reliability of our data collection process.

3.5 Data Collection Methods

The most frequently used techniques of data collection within the two basic research methods are the following:

- Review of relevant literature
- Interviews
- Questionnaires
- Observation

For the purposes of successfully carrying out this research study, a questionnaire was chosen as the preferred data collection instrument. The questionnaire was designed based on information gathered from the reviewed literature. After it had been approved for data collection, it was then distributed by email and through online data-gathering platforms to various respondents around the targeted area. After the respondents had completed filling out the questionnaire, the researchers gathered and filed the answers.

3.5.1 Instruments of Data Collection

The recommended data-gathering instrument for this study was a questionnaire. Questionnaires are regarded as an effective way of gathering a wide range of information from a large number of responders. Questionnaires are defined as a sequence of questions asked of persons to acquire statistically meaningful information about a specific topic (Wikipedia, n.d.). According to Burns and Grove (1993), a questionnaire is a printed self-report form meant to elicit information from the subject's written responses. When correctly designed and presented, surveys can be used to make statements about certain groups, individuals, or the entire community (Mofokeng, 2012)[48].

Questionnaires are considered advantageous based on the reason that they give the respondents time to think about the responses to the questions posed to them in the questionnaire. They are easily analyzed and are, in most cases, familiar to the participants; some people have had some sort of experience with completing questionnaires, therefore this reduces the participants' uneasiness in participating. Furthermore, questionnaires make it possible for a larger geographical area to be reached. Closed-ended or open-ended questionnaires are available. Respondents in open-ended questionnaires are required to write their responses in their own words. If responders choose, they may submit further information. According to Burns and Grove (1993), in closed-ended surveys, respondents are provided options linked to the research topic that are defined by the researcher. For the portions that require more uniform responses, a closed-ended questionnaire was used; nevertheless, in the initial section of the questionnaire, there is the opportunity to write the answers if the correct answer is not included in the selections.

The questionnaire was created by dividing it into three sections: The questionnaire was also developed in such a way that the participants' anonymity was not jeopardized since they were guaranteed that their identities would be kept private and would not be published with the research findings. The questionnaire included an expected time to complete the questionnaire, which was calculated through a pilot survey, as well as the researcher's contact information in case the respondents wanted clarification on anything in the questionnaire.

Section one was aimed at extracting demographic data. This is concerned with data such as gender, age, level of education, profession, and so forth, which would assist the researcher with the interpretation of the results. Section 2 of the questionnaire focused on gaining the industry perception of ISCPs. Section 3 was meant to evaluate the possible benefits of implementing ISCPs and their impact on the time, cost, and risk of the projects in a construction firm.

The validity and reliability of data-measuring instruments are crucial to scientific research (Brynard, 2014)[41]. Thus, content, criterion-related, construction, and external validity were carefully observed. Furthermore, attached to the questionnaire were instructions and guidelines to guide the respondents on how to answer the questionnaires.

Out of the 500 questionnaires sent out, 350 were recollected, representing a response rate of 300 percent. However, only one hundred and sixty-seven out of one hundred and seventy-one questionnaires were usable, which results in a usable response rate of eighty-four percent. These results formed the basis of this study, as summarised in the following Table:

Survey responses	Germany
Questionnaires sent out	500
Questionnaires collected	350
Usable questionnaires	300
Usable response rate (%)	60

Table 3.3 Questionnaire survey

Before analysis could be initiated, the collected data from the respondents had to be cleaned and screened. Frequency analysis of the raw data was then done using the Statistical Package for Social Sciences (SPSS).

3.6.2 Sampeling

Sampling is a fundamental aspect of research methodology, and it plays a pivotal role in the process of gathering and analyzing data (Brynard et al., 2014; Ashraf & Brewer, 2004)[41], [49]. Whether in the fields of social sciences, natural sciences, or even market research, sampling allows researchers to make inferences about a larger population based on a subset of that population. It often happens in research that the population being studied for a particular research study is of such magnitude that it could take the researcher years to complete the research (Brynard et al., 2014). Therefore, the researcher has to select from the population being studied a small group that is still representative of the general population being studied. This small group, which represents the larger population, is referred to as a sample. Sampling is the technique of selecting willing members of the population and involving them in a study so that the results are representative of the entire population. It is a technique employed to select a small group (the sample) to determine the characteristics of a large group (the population) (Ashraf & Brewer, 2004; Brynard et al., 2014). If selected critically, the sample will present the same characteristics as the large group. This thesis explores the intricacies of sampling techniques, their application in various disciplines, and the critical role they play in the generation of reliable research outcomes[41], [49].

Sampling is a convenient and cost-effective method for researching because it makes studying a representative sample of a population easier than studying the entire population. Also, sampling saves time because studying the entire population can be time-consuming, especially if it is very large or spread out over a large geographical area. Finally, sampling is thought to be a cost-effective method because collecting data from every single element of the population can be very costly, especially when one also takes into account the size of the population and how distributed it is.
In research terms, particularly for sampling, 'population' does not refer to the total number of citizens in a country. It refers to all objects, activities, phenomena, events, or cases the researcher wishes to study to establish new knowledge (Brynard et al., 2014)[41]. Therefore, it is important to determine which objects, activities, phenomena, events, or cases are to be considered as a population from which the sample will be selected for the study. It is also important to keep in mind that a larger sample is more representative of the population, making the conclusions to be drawn more accurate. The more heterogeneous a population is, the larger the sample should be (Bless & Higson-Smith, 1995). There are two categories of statistical sampling in the social sciences, according to Teddlie and Yu (2007) and Latham (2007), which are indicated as follows:
In the case of probability sampling, we can determine the probability that any element or member of the population will be included in the sample. The benefit of using probability sampling is that it allows us to show the likelihood of sample results varying to various extents from the corresponding population values.

- ✓ Examples of probability samples:
- ✓ Simple random samples
- ✓ Stratified random samples
- ✓ Systematic samples
- ✓ Cluster samples

Non-probability sampling is often associated with qualitative and case study research designs. Case studies typically focus on small samples to explore real-world occurrences rather than draw statistical conclusions about the entire population (Yin, 2003)[50]. While samples in non-probability sampling don't need to be random or representative, they should be chosen for specific reasons over others.

Examples of non-probability sampling include:

- Accidental or incidental samples

- Purposive samples

- Quota samples

- Snowball samples

- Convenience samples

Purposive or judgmental sampling involves deliberately selecting certain settings, individuals, or events to gather essential information not obtainable through other means (Maxwell, 1996)[51]. Quota sampling is a non-random technique where participants are chosen based on predetermined characteristics to mirror the population's distribution (Davis, 2005). Snowball sampling uses existing cases to encourage others to participate, particularly in closed or difficult-to-reach populations (Breweton and Millward, 2001). Convenience sampling involves selecting readily available participants, often chosen for its simplicity and low cost, especially common among students (Ackoff, 1953).

In our study, we utilized convenience sampling for pre-test validity by reaching out to experts to validate our questions before questionnaire distribution. For the final questionnaire submission, we employed purposive or judgmental sampling, deliberately targeting project managers in the European construction industry for their specific insights.

Chapter 4

Data analysis

This chapter presents the findings derived from the empirical investigation into the impact of integrated supply chain platforms on project management criteria in construction projects across Germany. Through the meticulous execution of the research methodology outlined in Chapter 3, this study sought to uncover insights into the relationships between the adoption of integrated supply chain platforms and the management of time, cost, and risk within construction projects. The analysis encompasses both quantitative and qualitative data obtained from targeted populations, employing a combination of inductive and deductive research approaches. The results are structured to provide a comprehensive understanding of the observed trends, patterns, and correlations, shedding light on the efficacy of integrated supply chain solutions in enhancing project management practices across across Germany.

4.1 Description of qualitative variables

Investigating the characteristics of the qualitative variables of ISCP users

In the first stage, we examine the qualitative characteristics of ISCP users in terms of job status, country, level of work experience, the amount of project capital, and the time it takes to deploy the system. Statistical values are calculated for each variable, in addition, graphical checks are also made.

❖ Job Level

Examining this variable shows that the job status of users is placed in 4 different categories, the most frequent of which belongs to the category of Frontline Management jobs. The relative frequency of this job category is 46.6%, followed by middle management with 41.8% and executive with 4.7%, the lowest job frequency of users, as shown in the table below.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Executive	14	4.7	4.7	4.7
	Middle Management	125	41.8	41.8	46.5
	Frontline Management	140	46.8	46.8	93.3
	Frontline Staff	20	6.7	6.7	100.0
	Total	299	100.0	100.0	

Table 4.2 Distribution of Job Levels among ISCP Users

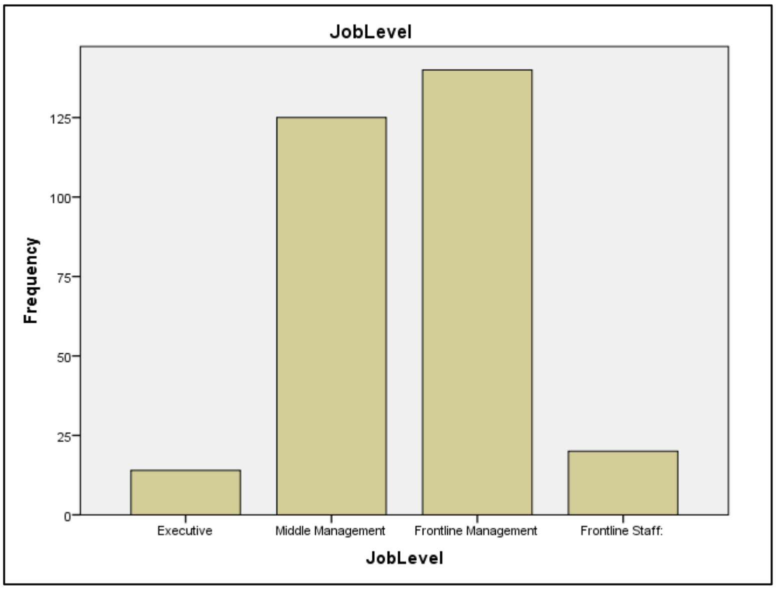

Figura 4.1 Bar chart distribution of Job Levels among ISCP Users

The following bar chart visually represents the distribution of job statuses among ISCP users. As discussed, the majority of users are categorized under Frontline Management jobs, comprising 46.6% of the total, followed by middle management with 41.8%, and executive roles with 4.7%. This graphical representation offers a clear visualization of the relative frequencies of each job category.

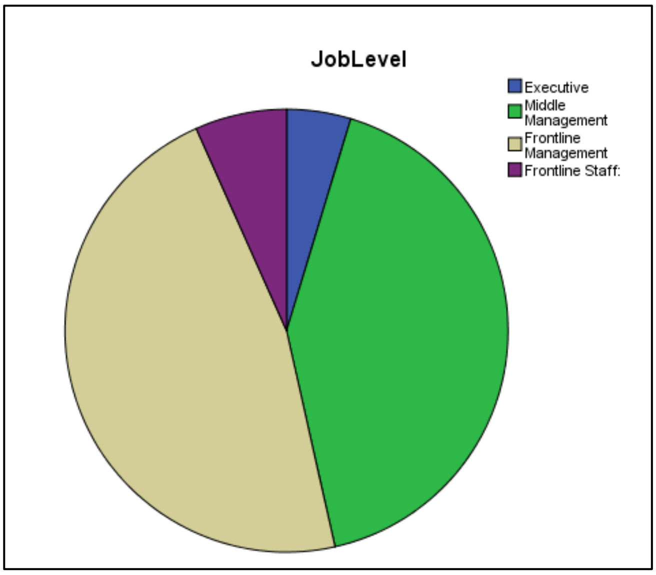

Figura 4.2 Pai chart distribution of Job Levels among ISCP Users

The pie chart illustrates the proportional breakdown of job statuses among ISCP users. This visual depiction offers a concise overview of the distribution of job statuses within the ISCP user base.

❖ Experience Level

Another important qualitative variable in this research is the level of skill and experience of ISCP users. In this research, users are placed in four skill levels: less than 5 years, between 5 to 10 years, between 10 to 20 years, and more than 30 years, which respectively have the highest frequencies with 47.8%, 27.4%, and 22.7% of users. With an experience of 5 to 10 years, less than 5 years, and between 10 and 20 years. It should be noted that none of the users have more than 30 years of experience. Meanwhile, the information about the experience level of 6 people is not in Desnares and it is considered as missing.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5 years	82	27.4	28.0	28.0
	5 to 10 years	143	47.8	48.8	76.8
	10 to 20 years	68	22.7	23.2	100.0
	Missing System	6	2.0		
	Total	293	98.0	100.0	

Table 4 3 Distribution of Experience Levelamong ISCP Users

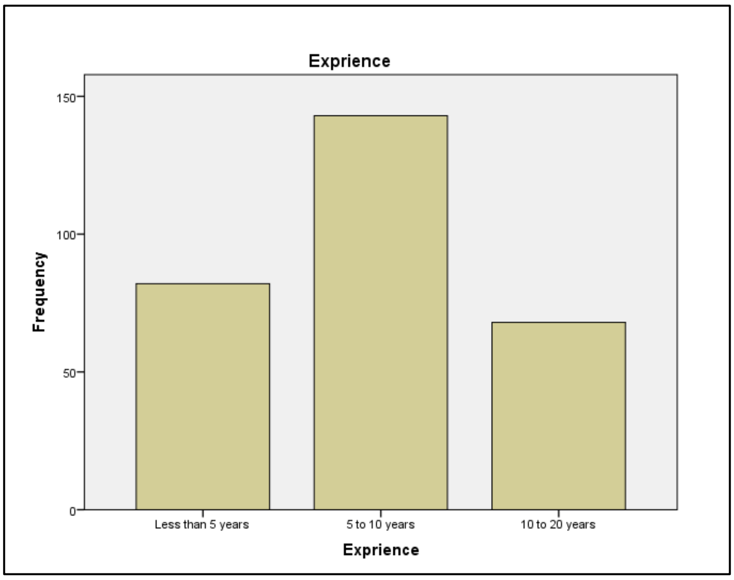

Figura 4.3 Bar chart distribution of Experience Levelamong ISCP Users

Above is a bar chart showing the skill and experience levels of ISCP users. The majority fall into the less than 5 years and 5 to 10 years categories, with none having more than 30 years of experience. Additionally, data for six individuals' experience levels is missing.

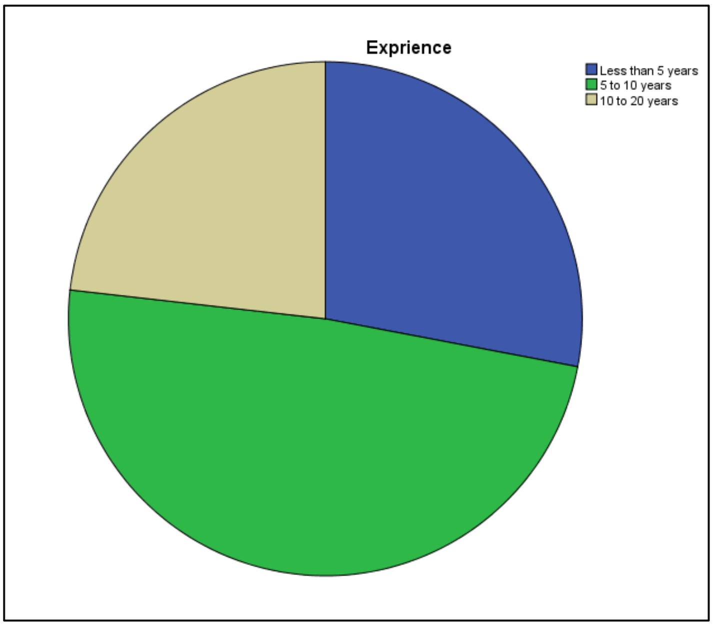

Figura 4.4 Pai chart distribution of Experience Levelamong ISCP Users

Above is a pie chart showing the distribution of skill and experience levels among ISCP users.

❖ Project Size

The economic volume of ISCP users' projects is another variable that looks qualitatively interesting and is also included in the current research, as we can see in the frequency table of this variable, users' projects in the four categories of Less than 1 M Euros, Between 1 to 10 M Euros, More than 10 M Euros and other items are placed. According to the opinion of users in this regard, the highest frequency of the economic volume of the projects is in the Less than 1 M Euros category with 36.8 percent, the Between 1 to 10 M Euros category with 29.8 percent, and the More than 10 M Euros category with 22.1 percent frequency. It is worth mentioning that 11.4% of users did not put the economic volume of their projects in these three categories. The table below also confirms this.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 M Euros	110	36.8	36.8	36.8
	Between 1 to 10 M Euros	89	29.8	29.8	66.6
	More than 10 M Euros	66	22.1	22.1	88.6
	Other	34	11.4	11.4	100.0
	Total	299	100.0	100.0	

Table 4.4 Distribution of Project Size among ISCP Users

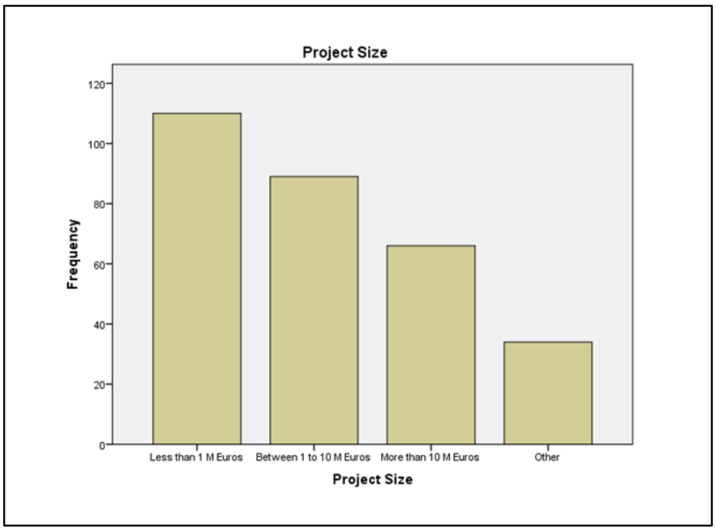

Figura 4.5 Bar chart distribution of Project Size among ISCP Users

The bar chart presented ISCP users' project size, with major categories ranging from Less than 1 M Euros to More than 10 M Euros. Notably, 11.4% of users did not specify their project's size within these categories.

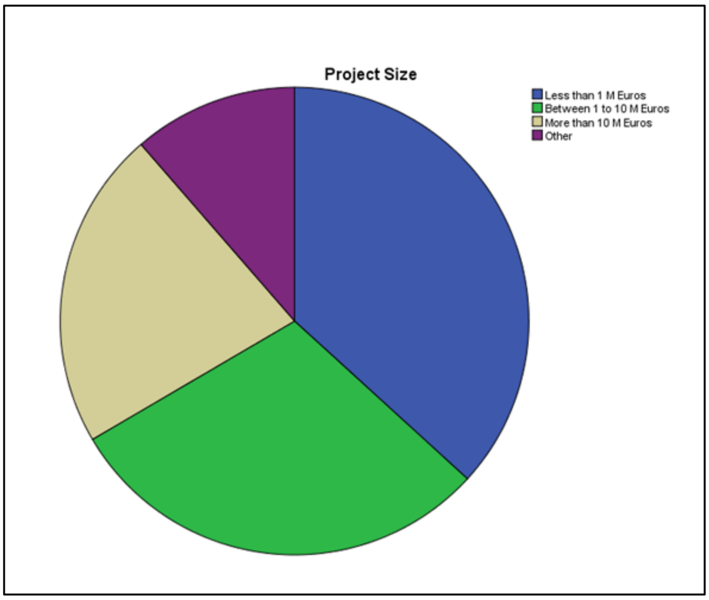

Figura 4.6 Pai chart distribution of Project Size among ISCP Users

The pie chart provided above illustrates the distribution of ISCP users' projects based on project size categories. It highlights the prevalence of projects falling within the Less than 1 M Euros, Between 1 to 10 M Euros, and More than 10 M Euros categories, offering a concise overview of project size distribution among users.

❖ ISCP Adaptation Time

The duration of using ISCP is another important variable, for this reason, this variable is also included in this research. For this purpose, we have categorized the duration of employment in four categories: under 1 year, between 1 and 3 years, between 3 and 5 years and more than 5 years. The results of the frequency table show that the most time of employment is between 1 and 3 years with 39.1% and then less than 1 year with 29.8% frequency. It is noteworthy that most users, 73.6% of people, have used ISCP for less than 5 years. The bar chart also shows the frequency of each category separately.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	89	29.8	29.8	29.8
	1-3 years	117	39.1	39.1	68.9
	3-5 years	14	4.7	4.7	73.6
	More than 5 years	79	26.4	26.4	100.0
	Total	299	100.0	100.0	

Table 4 5 Distribution of Adaptation Time among ISCP Users

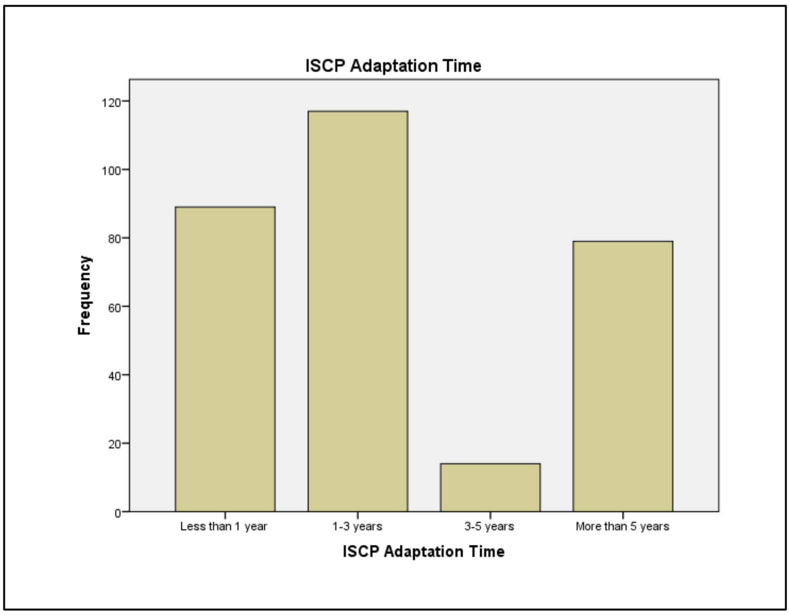

Figura 4.7 Bar chart distribution Adaptation Time of ISCP Users

The figure illustrates the distribution of adaptation time among ISCP users using a bar chart. It provides insights into the varying durations taken by users to adapt to the ISCP system

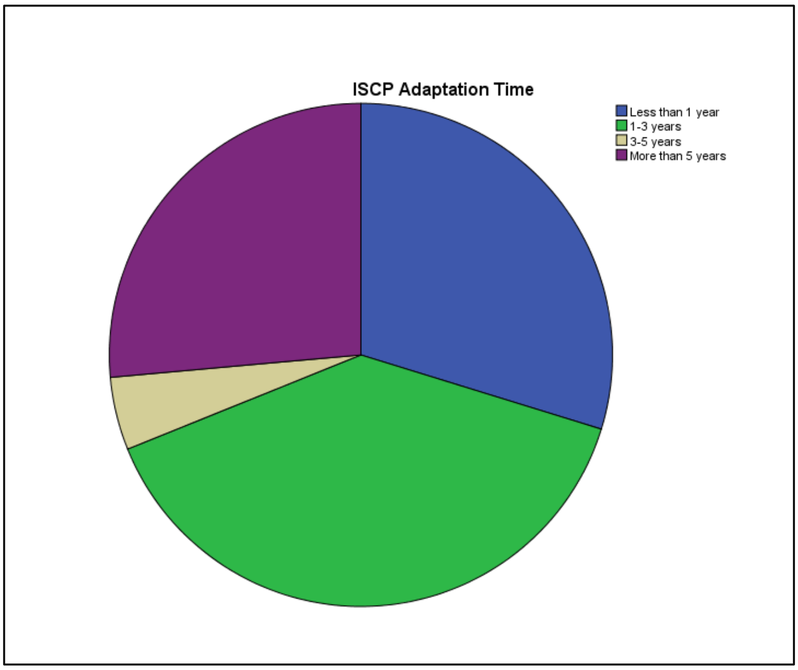

Figura 4.8 Pai chart distribution Adaptation Time of ISCP Users

The figure displays the distribution of adaptation time among ISCP users using a pie chart, offering a visual breakdown of the time taken by users to adapt to the ISCP system.

4.2 Description of Research Variables

In this section, the statistical analysis of the main variables of the desired research is done. In this research, three variables of time management, risk management, and cost management are examined, and each of these variables is asked by ISCP users through questions in the form of a questionnaire. The two variables of ISCPA and Performance have also been measured by 2 questions in the questionnaire from users. In this research, we are looking to investigate the effect of the ISCPA variable on these three managerial variables, the effect of the managerial variables on each other, and also to examine it on the overall performance of ISCP users. For this purpose, in the first step, we have provided a summary of the statistical information of the investigated variables.

Statistics					
	ISCPA	Time Management	Risk Management	Cost Management	Performance
Mean	2.4967	2.0134	2.3269	2.1781	2.1204
Median	2.5000	2.0000	2.2500	2.2500	2.0000
Variance	0.388	0.250	0.226	0.200	0.274
Skewness	0.328	0.093	0.684	0.535	0.176
Kurtosis	-0.280	0.766	0.609	0.703	0.399

Table 4.6 Statistical Analysis for Key Variables in ISCP Research

As seen in the table. Variables do not contain missing information. In each of the variables, the values of mean, median, variance, kurtosis and skewness are reported. For example, in time management, the average is 2.013, the median of the numbers is 2, and its length is 0.766. In the next step, the histogram of each of the variables is drawn, it is noteworthy that a representation of the normal distribution graph is also drawn on each of the graphs, which is a means to visually check the normal fit to each of the variables. Based on the graphs, it can be said that all variables in the model follow the normal distribution.

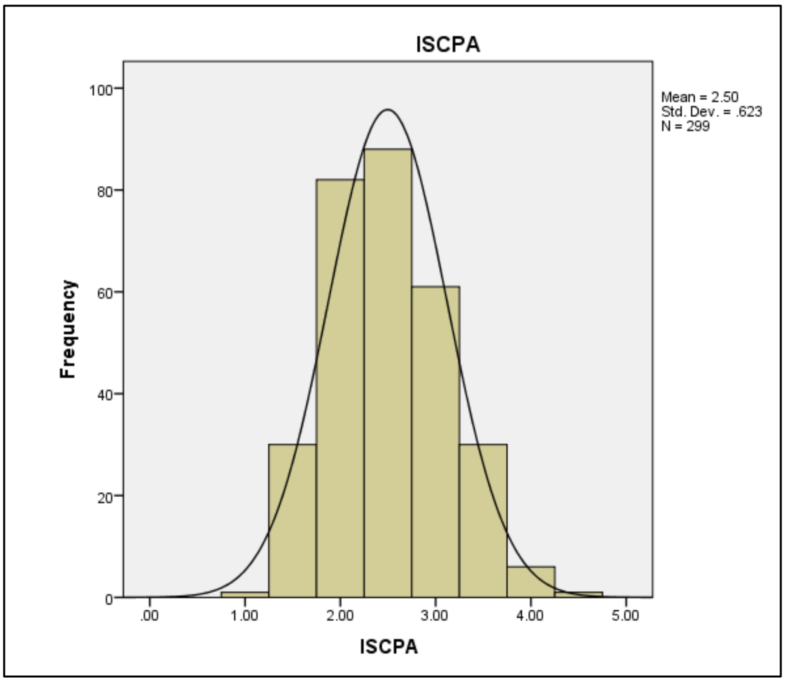

Figura 4.9 Normal Distribution ISCPA

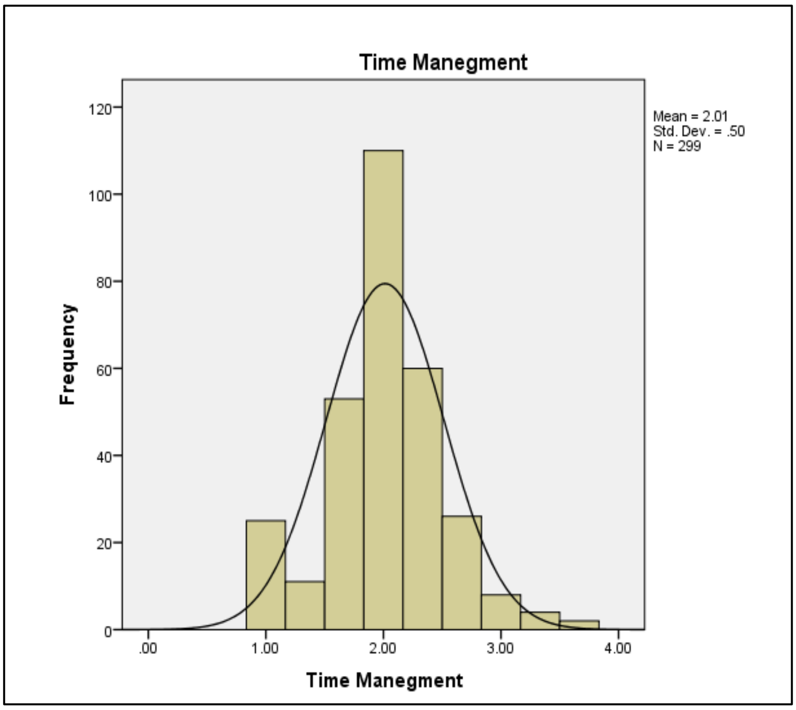

Figura 4.10 Normal Distribution of Time Management

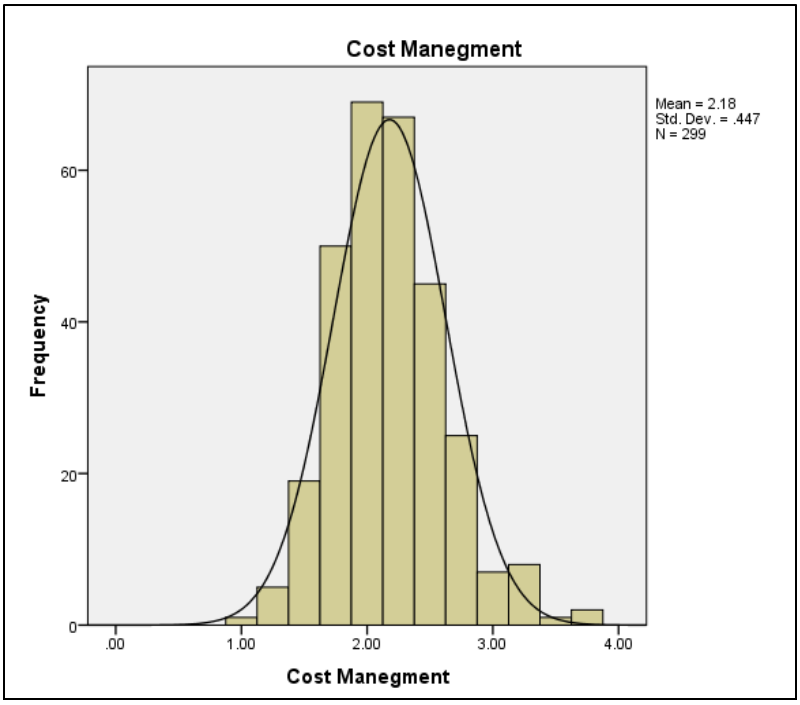

Figura 4. 11 Normal Distribution of Cost Management

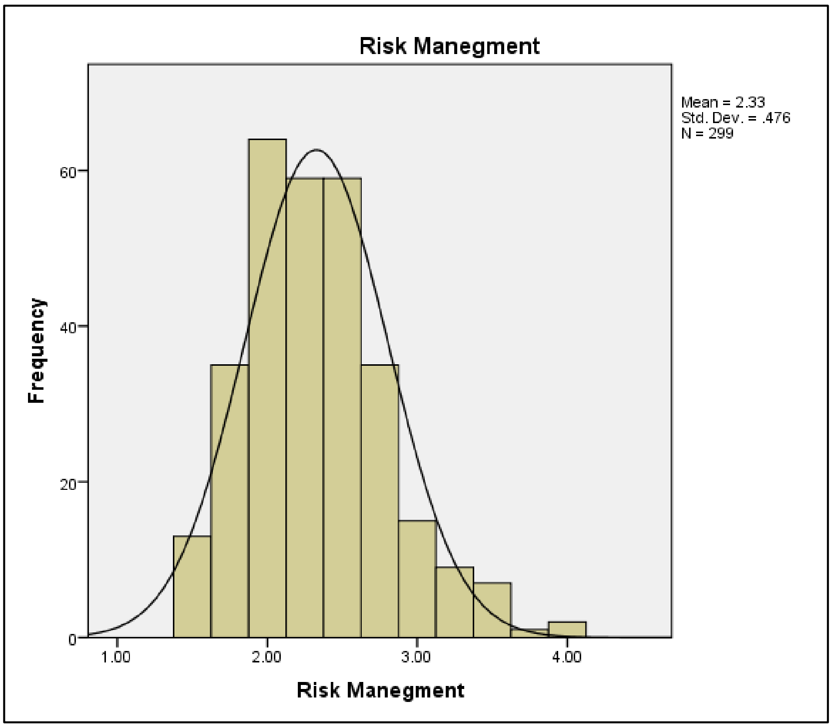

Figura 4.12 Normal Distribution of Risk Management

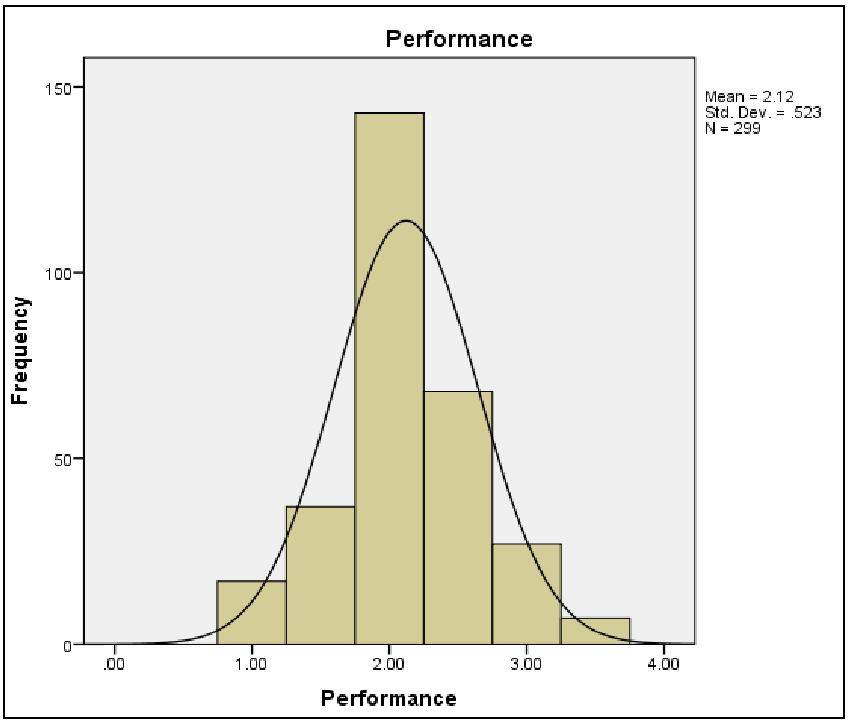

Figura 4.13 Normal Distribution of Performance

4.3 Inferential Findings

At first, for the statistical analysis of the data, Pearson's correlation test was used for the significance of the relationship between the variables. Pearson's correlation coefficient is a measure to measure the degree of linear relationship between two variables. In the table below, the values of the correlation coefficient between each pair of variables are calculated, and in each row, the P-value corresponding to the zero correlation test between the two variables is also given. We compare this value with 0.01 (0.05) and if the P-value is <0.01 (0.05), there is no scientific reason for the absence of a linear relationship between the two variables. It is noteworthy that the degree of positive correlation means the existence of a direct relationship (it means a relationship that increases (decrease) one variable, another variable also increases (decrease)) and negative correlation means the existence of an indirect relationship (it means a relationship that increases (decrease) One variable shows that the other variable decreases (increases) between two variables. As shown in the table below, significant relationships between variables are shown at the 0.01 error level with a ** sign and at the 0.05 error level with a * sign. given

correlations						
		ISCPA	Time Management	Cost Management	Risk Management	Performance
ISCPA	Pearson Correlation	1				
	Sig. (2-tailed)					
Time Management	Pearson Correlation	.126*	1			
	Sig. (2-tailed)	.030				
Cost Management	Pearson Correlation	.150**	-.007	1		
	Sig. (2-tailed)	.009	.905			
Risk Management	Pearson Correlation	.029	-.104	.210**	1	
	Sig. (2-tailed)	.615	.072	.000		
Performance	Pearson Correlation	.217**	.408**	.166**	.012	1
	Sig. (2-tailed)	.000	.000	.004	.843	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.7 Correlation Analysis Results for ISCP Research Variables

4.3.1 Structural equation model fitting

In this section, the fitting of the desired structural equation model and the examination of its results have been discussed. In this model, the final dependent variable is the overall performance of the ISCPA system. In the studied model, the effect of using the ISCPA system on user projects and its role in intermediate management variables including time, cost, and risk management have been measured. In the following, we will measure the role of management variables on the overall performance of the project. To analyze the final model of structural equations, two steps should be considered. First, the measurement models should be reviewed and the quality and appropriateness of the items in fitting the variables of ISCPA and time management, risk management, cost management, and project performance should be checked. In the next step, fitting the structural equations of the final model is considered. By examining the fit validity and reliability indices of the final model, we will examine the appropriateness and accuracy of the final model fit. Smart PLS 3 software was used to fit the structural equation model and the analysis steps are:

1. Drawing the model and estimating the regression coefficients
2. Significant investigation of the effect of each of the existing factors and sub-factors.
3. Checking the reliability of the structural equation model (with the help of Cronbach's alpha and composite reliability coefficient)
4. Examining the convergent validity of the model (AVE index)
5. Examining divergent validity (cross coefficients and Fornell-Larker index)
6. Investigating goodness of fit indices of structural equation models

4.3.1.Drawing the model and estimating the regression coefficients

In the first step, the final structural equation model is fitted as follows:

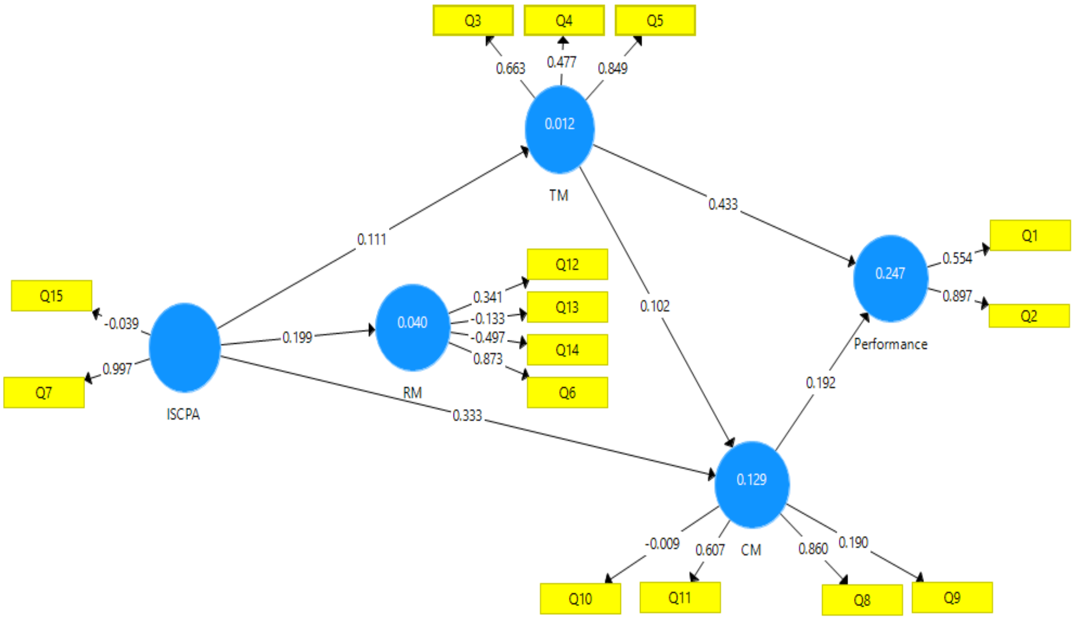

Figura 4.14 Structural analysis model related to investigating the role of managerial variables and ISCPA on project performance

In Figure 4.14, the yellow rectangles represent the items (the questionnaire questions) and the blue circles represent the hidden variables. The numbers on the arrows drawn between the latent variables and the items are the standardized factor loadings, and the numbers on the arrows connecting the two latent variables are the standardized path coefficients.

4.3.2 Significant investigation of the effect of each of the existing factors and sub-factors

After drawing the structural equation model and estimating the regression coefficients, the results of fitting the desired structural equation model according to the variables have been obtained as follows. We investigated the factor loads related to the studied structures. If these values are more than the critical value of 0.4, it indicates the appropriateness of the item (the desired question) in measuring the hidden variable. As can be seen, in the following we will examine the appropriateness of all the constructs and factor loadings obtained for all the items considered in the structural equation model for measuring ISCPA variables, risk management, time management, cost management, and performance.

	Coefficient	Standard Deviation	T Statistics	P-value	Significance
ISCPA->Q7	0.997	0.089	11.143	0.000	accepted
ISCPA->Q15	-0.039	0.235	0.168	0.068	rejected

Table 4.8 ISCPA variable measurement model

In the structure of ISCPA, the factor loadings related to questions Q7 and Q15 have the values of 0.995 and -0.039, respectively, it is worth mentioning that the questions related to project size and project time are also included in the ISCPA variable measurement model, and according to the factor loading (coefficients) down in the model, is removed from the model. This problem shows that the time to use this system and the size of the project used does not play an effective role in measuring ISCPA. The p-value values presented in the table can also conclude that the desired structure has a suitable structure with the presence of Q7 questions.

	Coefficient	Standard Deviation	T Statistics	P-value	Significance
Time Management->Q3	0.663	0.085	7.787	0.000	accepted
Time Management->Q4	0.477	0.123	3.884	0.000	accepted
Time Management->Q5	0.849	0.043	19.749	0.000	accepted

Table 4.9 Time Management variable measurement model

In the Time Management structure, the factor loadings related to questions Q3, Q4 and Q5 have the values of 0.663, 0.477 and 0.849, respectively, the presented p-values show that all the questions considered in this structure are meaningful and the desired structure With the presence of questions Q3, Q4 and Q5 have a proper structure.

	Coefficient	Standard Deviation	T Statistics	P-value	Significance
Cost Management->Q8	0.860	0.149	5.772	0.000	accepted
Cost Management->Q9	0.190	0.165	1.147	0.252	rejected
Cost Management->Q10	-0.009	0.186	0.051	0.345	rejected
Cost Management->Q11	0.607	0.151	4.104	0.000	accepted

Table 4 10 Cost Management variable measurement model

In the Cost Management structure, the factor loadings related to questions Q8, Q9, Q10, and Q11 have values of 0.860, 0.190, -0.009, and 0.607, respectively. The presented p-values show that the desired structure with the presence of questions Q8 and Q11 has a suitable structure.

	Coefficient	Standard Deviation	T Statistics	P-value	Significance
Risk Management->Q12	0.341	0.318	1.071	**0.000**	accepted
Risk Management->Q13	-0.133	0.317	0.418	**0.253**	rejected
Risk Management->Q14	-0.497	0.487	1.021	**0.351**	rejected
Risk Management->Q6	0.873	0.694	3.572	**0.000**	accepted

Table 4 11 Risk Management variable measurement model

In the Cost Management structure, the factor loadings related to questions Q8, Q9, Q10, and Q11 have values of 0.860, 0.190, -0.009, and 0.607, respectively. The presented p-values show that the desired structure with the presence of questions Q8 and Q11 has a suitable

	Coefficient	Standard Deviation	T Statistics	P-value	Significance
Performance ->Q1	0.544	0.127	4.380	**0.000**	accepted
Performance ->Q2	0.897	0.050	18.052	**0.000**	accepted

Table 4 12 Performance variable measurement model

In the Performance structure, factor loadings related to questions Q1 and Q2 have values of 0.544 and 0.897, respectively. The presented p-values show that all the questions considered in this structure are meaningful and the desired structure has a proper structure with the presence of questions Q1 and Q2.

4.3.3 Checking the reliability of the structural equation model (with the help of Cronbach's alpha and composite reliability coefficient)

	Cronbach's Alpha	Composite Reliability
Cost Management	**0.745**	**0.714**
ISCPA	**0.704**	**0.711**
Risk Management	**0.721**	**0.725**
Time Management	**0.874**	**0.821**
Performance	**0.738**	**0.725**

Table 4 13 Reliability indicators of research structures

Cronbach's alpha and composite reliability indexes are used to check the reliability of structures. The proximity of these indices to the value of 1 and greater than 0.7 indicates the existence of reliability within the structures. that the composite reliability coefficient is more reliable than Cronbach's alpha. In fact, the values of these coefficients should be more than 0.7. As can be seen, the studied structures are also reliable in terms of these indicators, and thus the structures considered in this model of structural equations, i.e. ISCPA, time management, risk management, cost management and performance are reliable.

4.3.4 Examining the convergent validity of the model (AVE index)

	Average Variance Extracted (AVE)
Cost Management	0.586
ISCPA	0.538
Risk Management	0.585
Time Management	0.528
Performance	0.556

Table 4 14 Validity index of convergence of research constructs

Regarding validity, two types of divergent validity and convergent validity are discussed. Convergent validity refers to the AVE index, which expresses the correlation between items related to a construct. To confirm the existence of convergent validity, the AVE index is expected to be more than 0.5. In all studied constructs i.e. ISCPA, time management, risk management, cost management, and performance, the existence of convergent validity between the items of each construct is confirmed.

4.3.5 Investigating divergent validity (Fornell-Larker index)

Divergent validity is also investigated by Fornell and Larcker method in the structures, the results of which are presented in the table below.

	Cost Management	ISCPA	Risk Managem ent	Time Management	Performance
Cost Management	**0.535**				
ISCPA	0.344	**0.706**			
Risk Management	0.218	0.199	**0.534**		
Time Management	0.139	0.111	0.082	**0.680**	
Performance	0.252	0.214	0.181	0.460	**0.745**

Table 4.15 Divergent validity index (Fornell Larcker method) of research constructs

As seen in Table 4.14, in the parts marked with dark color (bold), the AVE root value of each factor is higher than the correlation value of that factor with other factors. For example, in the risk management structure, the value of 0.534 is higher than the values of 0.082 and 0.181, and the divergent validity of this structure is confirmed. Therefore, we confirm the divergent validity of the factors related to all study constructs, i.e. ISCPA, time management, risk management, cost management and performance according to Fornell and Larcker method.

4.3.6 Examining the goodness of fit indices of the structural equation model

In this part, the evaluation indicators of the general model of structural equations have been investigated. For this purpose, two indices R^2 and Q^2 have been calculated and presented for each dependent variable. The R^2 index is one of the goodness of fit indices in structural equation models using the partial least squares method. The higher the value of R^2 related to the inner structures of the model, the better the fit of the model. Three values of 0.19, 0.31 and 0.67 have been introduced as criteria values for weak, medium and strong values of R^2.

	R Square	Results
Cost Management	0.329	Medium
Risk Management	0.312	Medium
Time Management	0.314	Medium
Performance	0.447	Medium

Table 4.16 R^2 index of model fit

Q^2 index is another index that can be calculated for each of the endogenous variables in the structural model. This measure determines the predictive power of the model. This criterion, which was introduced by Stone and Geiser, determines the predictive power of the model in endogenous constructs. According to them, the models with acceptable structural fit should be able to predict the endogenous variables of the model. This means that if in a model, the relationships between the structures are correctly defined, the structures have a sufficient impact on each other, and in this way, the hypotheses are correctly confirmed. According to Hensler et al., values of 0.02, 0.15, and 0.35 indicate low, medium, and strong predictive power for a structure, respectively.

	Q Square	Results
Cost Management	0.142	Medium
Risk Management	0.193	Medium
Time Management	0.152	Medium
Performance	0.212	Medium

Table 4.17 Q^2 index of model fit

According to Table 9, the Q^2 index for all the structures of the research model is more than 0.15, this shows that the model has moderate predictive power and confirms the appropriate fit of the structural model.

Evaluation of the overall fit index of the model

In the structural equation model approach by partial least squares method; The GOF index is the most complete index to check the efficiency of the overall model. This criterion, which was introduced by Tenenhaus, is estimated through the following formula.

$$GOF = \sqrt{\overline{AVE} \times \overline{R^2}}$$

In this formula, the average values of AVE and the average values of R^2 are used. According to Tenenhaus' proposal, three values of 0.1, 0.25 and 0.36 have been introduced as weak, medium and strong values to check the fit of the overall model using this index.

	Value	Results
GOF	0.597	Strong

Table 4.18 The overall fit index of the model

Based on the GOF value reported in Table 11, the goodness of fit index of the model is 0.597. This value shows that the appropriate fit of the overall model is confirmed.

Now that the appropriateness of the structural equation model has been confirmed based on the important and prominent indicators in this field, we will examine the statistical hypothesis test related to the research, which requires a meaningful examination of the regression paths, and we will discuss it further.

Significant investigation of regression paths

In this section, the aim is to investigate the cause and effect relationships of the studied model. For this purpose, the significance of regression effects of ISCPA user performance model paths has been investigated.

	Coefficient	Standard Deviation	T Statistics	P Values	Result
Cost Management -> Performance	0.192	0.060	3.198	0.001	accepted
ISCPA -> Cost Management	0.333	0.073	4.535	0.000	accepted
ISCPA -> Risk Management	0.199	0.202	1.984	0.032	accepted
ISCPA -> Time Management	0.111	0.074	2.021	0.013	accepted
Time Management -> Cost Management	0.102	0.069	2.014	0.014	accepted
Time Management -> Performance	0.433	0.050	8.631	0.000	accepted

Table 4.19 Investigating the regression effects of the ISCPA structural equation model

4.4 Analysis of Research Hypotheses

According to the results of Table 4.18, we will analyze the hypotheses of the research.

Hypothesis 1: ISCPA has an impact on cost management.

As presented in Table 4.18 and Figure 4.14, the estimate of the standardized path coefficient between ISCPA and cost management is 0.333. The value of the test statistic is greater than the critical value of 1.96 and the significance level is 0.032, which is less than α=0.05, and statistically, at the 95% confidence level, it can be concluded that there is a significant relationship between ISCPA and cost management.

Second hypothesis: ISCPA has an impact on risk management.

The estimation of the standardized path coefficient between ISCPA and risk management in Table 4.18 is 0.199. The value of the test statistic is 1.984, which is greater than the critical value of 1.96, and the significance level is 0.032, which is less than the critical value of α=0.05, and statistically, at the 95% confidence level, it can be concluded that there is a significant relationship between ISCPA and management There is risk. Therefore, the relationship between ISCPA and risk management is meaningful and ISCPA has an explanatory role in determining project risk management. It is noteworthy that the direct effect of ISCPA on risk management is 0.199, which means that with an increase of one unit of ISCPA, risk management will also increase by 19.9%.

The third hypothesis: ISCPA has an effect on time management.

Based on the values presented in Table 4.18 and Figure 4.14, the estimate of the standardized path coefficient between ISCPA and time management is 0.111. The value of the test statistic is 2.012, which is greater than the critical value of 1.96, and the significance level is less than α=0.05, and statistically, at the 95% confidence level, it can be concluded that there is a significant relationship between ISCPA and time management. Therefore, the relationship between ISCPA and time management is meaningful and ISCPA has an explanatory role in determining time management. The direct effect of ISCPA and time management is 0.111, which means that with an increase of one unit of ISCPA, time management also increases by 11.1%.

Fourth hypothesis: time management has an effect on cost management.

As presented in Table 4.18 and Figure 4.14, the estimate of the standardized path coefficient between risk management and cost management is 0.102. The value of the test statistic is greater than the critical value of 1.96 and the significance level is 0.014, which is less than α=0.05, and statistically, at the 95% confidence level, it can be concluded that there is a significant relationship between risk management and cost management. Therefore, the relationship between risk management and cost management is meaningful and risk management has an explanatory role in determining cost management. The direct effect of risk management on cost management is 0.102, which means that with an increase of one unit of risk management ISCPA, time management also increases by 10.2%.

Fifth hypothesis: time management has an effect on project performance.

As presented in Table 4.18 and Figure 4.14,the estimate of the standard coefficient of the path between time management and project performance is 0.433. The value of the test statistic is greater than the critical value of 1.96 and the significance level is less than α=0.05 and Statistically, at the 95% confidence level, it can be concluded that there is a significant relationship between time management and project performance. Therefore, there is no significant relationship between time management and project performance.

Sixth hypothesis: cost management has an effect on project performance.

Based on the values presented in Table 4.18 and Figure 4.14, the estimate of the standardized path coefficient between cost management and project performance is 0.192. The value of the test statistic is 3.198, which is greater than the critical value of 1.96, and the significance level is less than α=0.05, and statistically, at the 95% confidence level, it can be concluded that there is a significant relationship between cost management and project performance. Therefore, the relationship between cost management and project performance is significant, and cost management has an explanatory role in determining project performance. The direct effect of cost management on project performance is 0.192, which means that by increasing one unit of cost efficiency, project performance also increases by 19.2%.

Chapter 5
Findings and Discussion

5.1 Introduction

This chapter presents a comprehensive synthesis of the findings from the empirical investigation detailed in Chapter 4, focusing on the impact of Integrated Supply Chain Platforms (ISCPs) on project management criteria within the construction industry in Germany. By rigorously analyzing the collected data, this study aims to answer the research questions outlined in Chapter 1 and explore the theoretical and practical implications of ISCP adoption on project performance, particularly in terms of time, cost, and risk management. We delve into empirical evidence that supports the positive impact of ISCPs on project efficiency, financial control, and risk mitigation, while also addressing the limitations of the current study and proposing avenues for future research. This chapter strives to offer a concise yet comprehensive analysis of the effects of ISCP adoption on project management in German construction projects, providing valuable insights for both academia and industry practitioners.

5.2 Overview of Findings

The research aimed to elucidate the effects of ISCP adoption on project performance, with a particular emphasis on time management, cost management, and risk management in construction projects. The findings from Chapter 4 indicate that ISCPs significantly enhance project management by improving efficiency, reducing costs, and mitigating risks associated with construction projects.

5.2.1 Characteristics of ISCP Users

Our study delved into the distinctive traits of ISCP users, encompassing job level, experience, project scope, and adaptation time. The analysis unveiled that a substantial portion of users occupied frontline management roles, with notable representation from middle management. Moreover, a noteworthy revelation was the prevalence of relatively inexperienced individuals, with a significant proportion having less than five years of industry tenure. Additionally, a considerable number of projects overseen by ISCP users were categorized under lower economic volumes, with a substantial percentage adopting ISCPs within the previous one to three years.

These findings collectively shed light on the diverse demographic and project-related landscape of ISCP users, underscoring the need for tailored strategies to address the varying needs and challenges within this user base.

5.2.2. Impact of ISCP Adoption on Project Management

The findings indicated a positive association between ISCP adoption and various aspects of project management, including time, cost, and risk management. ISCP users reported improvements in project scheduling efficiency, financial control, and risk mitigation effectiveness compared to traditional supply chain management techniques. Moreover, the analysis revealed that ISCP adoption contributed to enhanced overall project performance, as evidenced by improved project outcomes and success rates.

5.2.3 Discussion

Our findings underscore the widespread acknowledgment among construction project stakeholders regarding the pivotal role of integrated supply chain platforms (ISCPs) in achieving enhanced project management performance. While the majority of construction project entities recognize the significance of leveraging ISCPs for improved project outcomes, a minority have yet to fully embrace this transformative approach.

Aligned with previous research, our study reveals a positive correlation between ISCP adoption and enhanced performance in construction project in Germany. This affirmation resonates with prior studies such as those conducted by Cornelia Droge, which demonstrate the tangible benefits of ISCPA on time management (TM). Notably, ISCPA, encompassing both external strategic design integration and internal design-process integration practices, significantly enhances time-based performance.

Moreover, the positive association between ISCPA and cost management (CM) is evident, as elucidated by Peter Kelle's research. By facilitating efficient data exchange among supply chain partners, ISCPA contributes to minimizing overall supply chain costs, thereby optimizing cost management within construction projects.

Furthermore, our study confirms the substantial impact of ISCPA on risk management (RM), echoing the insights provided by Mandičák et al. and Hatmoko. By leveraging emerging digital technologies and fostering real-time visibility into the supply chain, ISCPs play a crucial role in mitigating delays and disruptions, ultimately enhancing project resilience and success.

The findings of our study align with the broader literature, emphasizing the importance of effective supply chain management and risk mitigation capabilities in driving construction project success. By sensitizing construction project professionals to the significance of ISCP adoption and the development of supply chain risk management (SCRM) capabilities, our research contributes to advancing understanding in this critical area.

In conclusion, our study underscores the imperative for construction project entities to embrace integrated supply chain platforms as a strategic imperative for achieving better project management performance, cost optimization, and risk mitigation in an increasingly complex and uncertain operating environment.

The findings contribute to the theoretical understanding of the role of ISCPs in enhancing project management practices in the construction industry. By demonstrating the positive impact of ISCP adoption on project performance, the study supports existing literature emphasizing the importance of information technology in supply chain management. The findings also highlight the need for further research to explore the mechanisms through which ISCPs influence project management outcomes.

5.3 Answering the Research Questions

Research Question 1: Impact of ISCPs on Project Performance and Success Rate

The empirical evidence gathered from the German construction industry unequivocally demonstrates that ISCPs markedly enhance project performance and success rates. Specifically, projects utilizing ISCPs have shown significant improvements in adherence to timelines, budget accuracy, and the effective management of project-associated risks. The adoption of ISCPs facilitates a holistic integration of project management processes, leading to streamlined operations and optimized resource allocation. These platforms serve as catalysts for real-time communication and collaboration among stakeholders, fostering a proactive management culture that inherently boosts project success rates.

Research Question 2: Time Management Benefits from ISCP Adoption

The study identifies several key time management benefits attributable to the adoption of ISCPs in construction projects. Notably, ISCPs have revolutionized project scheduling by enabling dynamic adjustments and real-time updates, thus ensuring timely project completion. Furthermore, these platforms enhance the precision of project planning stages, mitigate delays through efficient resource allocation, and enable the early detection of potential schedule disruptions. The net result is a marked reduction in time overruns, contributing significantly to the timely delivery of construction projects.

Research Question 3: Efficiency of Cost Management in ISCP-utilizing Projects

ISCPs have profoundly impacted cost management practices within construction projects. The study reveals that ISCPs contribute to more accurate budget forecasts, enhanced monitoring of ongoing expenses, and a notable reduction in cost overruns. By facilitating an integrated view of financial data, these platforms allow for more informed decision-making, ensuring that projects remain within budget. Moreover, the transparency and real-time data access provided by ISCPs empower project managers to identify and address cost-related issues promptly, thus maintaining financial control throughout the project lifecycle.

Research Question 4: Improvement in Risk Management through ISCP Usage

The adoption of ISCPs significantly bolsters risk management capabilities in construction projects. These platforms provide comprehensive tools for risk identification, analysis, and mitigation planning, thereby enhancing the project team's ability to manage uncertainties effectively. Through ISCPs, project managers gain access to predictive analytics and simulation tools, enabling them to anticipate potential risks and formulate proactive mitigation strategies. Consequently, projects benefit from reduced incidences of unexpected issues, minimized disruptions, and improved overall risk posture.

Research Question 5: Variability of ISCP Impacts across European Contexts

While this study focuses on the German construction industry, preliminary findings suggest that the positive impacts of ISCP adoption on time, cost, and risk management are likely to extend beyond national boundaries. Future research is encouraged to explore the application and effects of ISCPs across different European countries, aiming to validate the generalizability of these benefits and identify any contextual variations that may influence platform efficacy.

Research Question 6: Perceptions of Construction Project Managers on ISCP Impacts

The feedback from construction project managers underscores a strong perception of the positive impact of ISCPs on project management practices. Managers highlight the platforms' role in enhancing operational efficiency, improving financial oversight, and strengthening risk management. Their experiences emphasize the importance of user training and platform adaptability to maximize benefits. The insights garnered underscore a broad consensus on the value of ISCPs, reflecting both the tangible improvements in project outcomes and the strategic advantages gained through technology adoption.

5.4 Practical Implications

Theoretically, this study contributes to the body of knowledge on supply chain management and project management by demonstrating the pivotal role of technology in enhancing construction project outcomes. Practically, it offers insights for construction firms and project managers on the benefits of integrating ISCPs into their project management practices, highlighting the necessity for strategic planning and implementation of such platforms.

5.5 Future Research Directions

While this study has provided valuable insights into the impact of Integrated Supply Chain Platforms (ISCPs) on project management within the German construction industry, it also opens up several avenues for future research. These directions not only aim to expand our understanding of ISCPs but also to explore new territories within the realm of supply chain management and construction project management.

5.4.1 Comparative Cross-Country Analysis

Future studies could undertake a comparative analysis of the adoption and impact of ISCPs across different European countries or even on a global scale. Such research could highlight cultural, economic, and regulatory factors influencing ISCP effectiveness and adoption rates. A cross-country comparison would also provide insights into best practices and strategies that could be universally applied or adapted to local contexts.

5.4.2 Longitudinal Studies on ISCP Adoption

Longitudinal research tracking the long-term effects of ISCP adoption on construction projects would be highly beneficial. These studies can provide deeper insights into how the sustained use of ISCPs influences project management criteria over time, including the identification of any emerging trends, benefits, or challenges that may not be apparent in short-term analyses.

5.4.3 Integration of Emerging Technologies

There's a growing potential for integrating emerging technologies such as artificial intelligence (AI), machine learning, and blockchain with ISCPs. Future research could explore how these technologies enhance the functionalities of ISCPs, particularly in automating complex supply chain tasks, improving data security, and enabling more intelligent decision-making processes.

5.4.4 Impact of ISCPs on Sustainability and Green Building Practices

As sustainability becomes increasingly important in construction, future studies could investigate how ISCPs contribute to sustainable building practices. This includes examining ISCPs' role in optimizing resource use, reducing waste, and facilitating the implementation of green building initiatives.

5.4.5 User Experience and Human Factors

Further research is needed to explore the human factors and user experience aspects of ISCP adoption. Studies focusing on the usability, user satisfaction, and training requirements associated with ISCPs can provide insights into barriers to adoption and how these platforms can be designed to better meet the needs of construction professionals.

5.4.6 Sector-Specific Impacts of ISCPs

The construction industry is diverse, encompassing residential, commercial, and infrastructure projects, each with unique challenges. Future research could delve into how ISCPs impact these different sectors of the construction industry, potentially leading to sector-specific adaptations of ISCP functionalities.

5.4.7 Development of a Standardized ISCP Adoption Framework

There is a need for a standardized framework guiding the adoption and implementation of ISCPs in construction projects. Such a framework could be developed based on empirical research findings and expert consensus, providing a roadmap for construction firms looking to integrate ISCPs into their operations.

Conclusion

These future research directions not only underscore the significant potential for further exploration within the domain of ISCPs but also highlight the interdisciplinary nature of this field, encompassing technology, management, sustainability, and user experience. As the construction industry continues to evolve, so too will the opportunities for enhancing project management practices through the adoption of ISCPs and related technologies.

Appendix

ISCP effect on PM-Germany

In this questionnaire you are asked to give your response on the impact of integrated supply chain management platforms on the project management criteria in the construction industry.
There is a demographic section followed by 14 multiple choice questions. Thanks for your participation.

Name

Your answer

Email

Your answer

Position/Role

Your answer

Country

Your answer

Company/Organization Name

Your answer

How many years have you been working in the construction industry? Your answer
Size of the projects you have been working with (please provide an average) ◯ Less than 1 million Euros ◯ Between 1 to 10 million Euros ◯ More than 10 million Euros
Have you or your organisation adopted an integrated supply chain platform for construction projects? 1. Yes 2. No
If you have adopted the ISCP in your organisation, please provide the name of the platform: Short answer text
How long have you been using this integrated supply chain platform? ◯ Less than 1 year ◯ 1-3 years ◯ 3-5 years ◯ More than 5 years
1. In your experience, how has the adoption of the integrated supply chain platform impacted overall performance considering factors such as meeting project timelines, achieving project scope, staying within the budget in construction projects?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

2. In your experience, how has the adoption of the ISCPs impacted the overall project success rate, based on your company specific metrics, and factors like stakeholder engagement and satisfaction?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

3. In your experience, how has the adoption of the integrated supply chain platform impacted overall time management in construction projects?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

5. In your experience, how has the adoption of the integrated supply chain platform impacted project delays that are the direct result of the supply chain activities?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

6. In your experience, how has the adoption of the integrated supply chain platform impacted the reduction in order errors?

◯ Significantly improved ◯ Moderately improved ◯ No significant impact ◯ Moderately deteriorated ◯ Significantly deteriorated
7. In your experience, how has the adoption of the integrated supply chain platform helped to eliminate unnecessary management processes related to the supply chain activities? ◯ Significantly improved ◯ Moderately improved ◯ No significant impact ◯ Moderately deteriorated ◯ Significantly deteriorated
8. In your experience, how has the adoption of the integrated supply chain platform impacted overall cost management in construction projects in your organisation? ◯ Significantly improved ◯ Moderately improved ◯ No significant impact ◯ Moderately deteriorated ◯ Significantly deteriorated
9. In your experience, how has the adoption of the integrated supply chain platform impacted the reduction in unnecessary inventory? ◯ Significantly improved ◯ Moderately improved ◯ No significant impact ◯ Moderately deteriorated ◯ Significantly deteriorated
10. In your experience, implementing ISCP in projects has prevented cost overruns, keeping the project budget within scheduled budget?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

11. In your experience, in the case of expenditures exceeding the budgeted cost, how has the adoption of the integrated supply chain platform impacted improved project cost control, especially to bring back the cost to the scheduled budget?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

12. In your experience, how has the adoption of the integrated supply chain platform impacted overall risk management in construction projects?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

13. In your experience, how has the adoption of the integrated supply chain platform improved real-time project tracking, enabling timely responses to any risk that becomes more probable to occur?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

14. In your experience, how has the adoption of the integrated supply chain platform, if they help the risk identification, can help in the mitigation as well?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

15.How extensively is the digital supply chain platform integrated into your project management processes?

- Significantly improved
- Moderately improved
- No significant impact
- Moderately deteriorated
- Significantly deteriorated

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