Impact of Integrated Supply Chain Platforms on Construction Project Management

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Abstract

Supply chain challenges in the construction industry often lead to cost and time overruns, making it imperative to enhance supply chain management. To offer a tool to construction decision-makers, this study investigates the impact of Integrated Supply Chain Platforms (ISCP) on construction project management in the context of Nordic European countries by exploring the effectiveness of integrated software platforms and their influence on project outcomes, focusing on time, cost, and risk management. Utilizing Structural Equation Modeling, the study examines the interplay between ISCP adoption, time management, cost management, and risk management. Results indicate a high satisfaction level among ISCP users, particularly in risk, time, and cost management. The structural equation model analysis demonstrates the positive influence of ISCP adoption on risk and time management, indirectly affecting cost management and overall project performance. The study identifies the significance of prolonged ISCP adoption in improving risk and time management. While ISCP does not directly impact cost management, its indirect influence, mediated through time management, enhances project performance. The findings contribute to understanding the role of digital technologies in optimizing construction supply chains, emphasizing the need for specific sub-frameworks for digital supply chain implementation in the construction industry.

Keywords

Integrated Supply Chain Platforms; Construction; Risk Management; Cost Management; Time Management

1 Introduction

Information constitutes a key instrument in decision-making for the supply chain. Gaining power from information would likely allow industries dealing with supply chain challenges to exert more control over their suppliers and improve their supply chain management capabilities [1].

In the supply chain, information is frequently used to achieve two objectives [2]: first, organizing everyday operations related to manufacturing, storage, positioning, and transportation; and second, using forecasting and planning to predict future demand and determine the necessary steps to requirements. Effective information dissemination and transmission can enhance all supply chain management components. Information Technology (IT) thus plays a major role in the digitalization of SC information management processes [3].

Planning and operational decision-making can benefit greatly from accurate and timely information managed through information technologies under the umbrella of Enterprise Resource Planning. This is an integrated information system that unifies internal data processing operations, merges operational data and integrates enterprise internal function working processes [4].

Data produced by various Enterprise Resources Planning systems are widely used to create integration with customers, suppliers, or both since they deliver accurate and timely information that will result in supply chain integrity. An Enterprise Resource Planning system offers high levels of cross-functional integration across sales, marketing, and other departments, employs tried-and-true business processes for decision-making, and has the capacity to connect clients and suppliers into a full supply chain [5, 6].

The construction industry traditionally has conceived the supply chain as troublesome and a complicated process often resulting in cost and time overruns. The construction sector is known for its poor performance and limited margins of profit [7]. Waiting, handling materials, and other indirect labor accounted for more than 80% of the typical Swedish craftsmen's working day [7].

Construction sector supply chains may be quite intricate due to the complex interrelations between a vast array of suppliers and subcontractors with heterogeneous objectives, priorities, and organizational values. Supply chain disruptions trigger multiple underperformance on construction projects, as reflected during the recent global crises. Increasing construction project productivity requires strengthening the supply chain throughout the project's life cycle [8-10].

Digital technologies can improve supply chain processes to guarantee a prompt response to construction project needs. Digital supply chains are conceptualized as a set of inter-organizational systems that companies adopt to digitize transactional and collaborative processes with their supply chain partners, including upstream suppliers and downstream customers [11].

The primary technological advancements with the most significant impact on the digital supply chain are big data and cloud computing [12].

The integration of technology into supply chain management can result in various benefits, such as reducing operational costs and improving stakeholders' satisfaction allowing an efficient, adaptable, and responsive supply chain, which leads to shorter lead times and greater product availability [13]. There is a significant research gap when it comes to evaluating the effect of digital technology applications on construction supply chains in a holistic and objective manner [14]. There an heterogenous policies, approaches, and practices for implementing digital supply chains within the construction industry. Further research is necessary to develop specific sub-frameworks for digital supply chains in the construction industry. Hence, having a proper guideline and framework for implementing a digital supply chain is essential to facilitating the digital transformation of the construction industry [15].

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 project outcomes. The research problem for this topic is to understand the influence and implications of integrated supply chain platforms on construction project management criteria in the context of construction projects in Nordic European countries (Denmark and Norway) using Structural Equation Modeling. These countries were chosen because of their advanced digital infrastructure and high levels of technology adoption, their similar economic structures, regulatory environments, and construction standards.

Among the criteria for project management, this study focused on time, cost, and risk management as the parts that could be influenced by the implementation of the integrated software platforms. By using a survey, the validity of the proposed model will be examined, and the degree of influence of the software utilization on different aspects of the project management within the construction industry.

2 Research Methods

The conceptual causal model that illustrates the relationship between the Integrated Supply Chain Platform Adoption and Project Performance was first designed based on theoretical background.

Based on the literature review conducted, key parameters were considered; each represents a critical aspect related to the integrated supply chain platform adoption (ISCPA) in the context of time management (TM), cost management (CM), and risk management (RM) within construction projects, as shown in Table 1. Based on these parameters and their interactions and relations, the latent variables and indicators were built.

Table 1. Acronyms Indicators Analyzed

Symbol	Indicator
Q1	Performance (timelines, scope, budget)
Q2	Stakeholder engagement and satisfaction
Q3	Construction time management
Q4	Lead times for materials
Q5	Project delays
Q6	Order errors
Q7	Unnecessary supply chain processes
Q8	Cost Management
Q9	Unnecessary inventory
Q10	Scheduled budget
Q11	Bringing back the cost to the scheduled budget
Q12	Risk Management
Q13	Real-time project tracking
Q14	Risk identification and mitigation

The Integrated Supply Chain Platform Adoption represents the extent to which construction firms adopt and integrate digital supply chain platforms into their project management processes. This latent variable is composed of indicators that consider factors like technology adoption, information sharing, collaboration, visibility, and transparency.

Time Management assesses the efficiency and effectiveness of project scheduling, project delays, and overall project time performance within construction projects. This latent variable is evaluated based on various time-related metrics and indicators, including project duration, critical path analysis, schedule adherence, and time-related deviations.

Cost Management assesses financial control and expenditure monitoring within construction projects derived from the management of total project costs, avoiding cost overruns, controlling expenses, and adhering to budgetary constraints. This construct encompasses factors such as cost estimation accuracy, cost tracking, cost overruns, and financial control mechanisms.

Risk Management focuses on the identification, assessment, mitigation, and response to risks within construction projects. This latent variable 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).

The model tests eight hypothesis regarding relationships among our latent variables: Integrated Supply Chain Platform Adoption, Time Management, Cost Management, and Risk Management.

The first hypothesis is related to the influence of Integrated Supply Chain Platform Adoption on Cost Management [16]. The second hypothesis asserts that there exists a positive relationship between the Integrated Supply Chain Platform Adoption and Risk Management [17]. The third hypothesis supports that a higher level of Integrated Supply Chain Platform Adoption will increase the level of coordination among stakeholders and thus positively influence Time Management within construction projects [18]. The fourth hypothesis establishes that Cost Management will result in better overall performance in construction projects, through affecting time, cost, and risk management. The fifth hypothesis establishes that Risk Management can enhance Cost Management. Proficient Risk Management is anticipated to have a positive impact on Cost Management by preventing incurred costs due to risk occurrence. The sixth hypothesis presumes that Risk Management can enhance Time Management. The seventh hypothesis asserts that Effective Time Management is expected to have a positive influence on construction Cost Management. The last hypothesis establishes that Time Management will result in a better overall performance in construction projects, through affecting time, cost, and risk management. Time management, facilitated by the adoption and integration of Integrated Supply Chain Platforms, directly influences project timelines, ensuring projects are completed within scheduled durations. Indirectly, by enhancing efficiency and coordination, it reduces costs associated with delays and mismanagement. Furthermore, it aids in risk identification and mitigation by allowing more proactive project management.

The current study used a survey research design. A questionnaire was developed for data collection and testing hypotheses. The questions were formulated based on relevant extant literature supporting the measure of each construct [1,4,6,11,14,15]. The questionnaire included different sections representing items of each construct. A five-point Likert scale is used to measure each item. In this study, the unit of analysis stands for the professionals having working experience in organizations dealing with construction projects in two Nordic European countries.

3 Findings

In order to test our hypothesis on the effects of the ISCP on project management in the construction study, we used a questionnaire as the basis for building the Structural Equation Model.

3.1 Characterization of Respondents

Out of the 594 questionnaires sent out, 197 answers were recollected, representing a response rate of 33% percent, which is larger than similar studies that achieved rates of 16%, 27%, and 28%, respectively [19,20,21]. The initial cleaning process, eliminated 25 of the responses, mainly because either the job position was not related, or they did not use the Integrated Supply Chain Platform in their company or the countries were outside the desired ones.

In the first stage, it was investigated the qualitative characteristics of the Integrated Supply Chain Platforms users concerning their job position, country, level of work experience, project size, software platforms utilized, and time since such a system has been used in the construction project organization. For each variable, statistical values are calculated, accompanied by graphical analyses for a comprehensive understanding.

Analysis of this variable indicates that the job position of users falls into 18 different categories, with the highest frequency belonging to the Project Manager, job category. The relative frequency of this job category is 61.6%, which is in line with the main objectives of the research. Following that, "project director" has the next highest frequency at 17.4%, and "PM assistant" constitutes the majority of users' job frequencies with 8.1%.

To deal with this variable more conveniently, the users' experience level was categorized into 3 main categories. In this research, users are classified into three skill levels: Junior (between 1 to 4 years of experience), Senior (between 5 to 9 years of experience), and Experienced (10 years and beyond). Senior respondents represent the majority of the study's population, accounting for 51.2% of the users. This high percentage suggests that over half of the participants have relevant experience. Experienced respondents make up 35.5% of the participants, indicating that more than a third of the users have extensive experience. Conversely, Junior respondents represent a smaller portion, constituting only 13.3% of the participants, indicating that a lesser fraction of the respondents are at an incipient stage of their professional journey in the field.

The size of the projects undertaken by the Integrated Supply Chain Platforms users is another qualitative variable considered in the present study. Users' projects fall into three categories: Less than 1 M Euros, Between 1 to 10 M Euros, and More than 10 M Euros. According to users, the highest frequency of economic project scale is, in order, in the category Between 1 to 10 M Euros at 44.8%, followed by Less than 1 M Euros at 34.9%, and More than 10 M Euros at 20.3%. Overall, 79.9% of the respondents are managing projects with values less than 10 M Euros.

The next variable under qualitative examination is the Software platforms employed by users to manage the supply chain in their projects. 16 different software platforms were identified. This variety indicates that the data encompasses responses from different user groups employing a broad spectrum of software solutions for their supply chain management needs. Among these systems, Primavera has the highest frequency percentage (12.8%), surpassing all other systems used. Following that, Oracle Fusion Cloud and NetSuite, with frequencies of 12.2% and 11% respectively, have garnered the most significant representativeness within the construction industry.

The duration of the Integrated Supply Chain Adoption is another crucial variable and has been considered in the present study for its significance. This focus is underpinned by the assumption that an extended period of software adoption correlates with improved organizational proficiency in utilizing and integrating the software. Prolonged engagement deepens users' comprehension and operational proficiency, which enhances understanding not merely about mastering the software but about integrating it effectively within the complex ecosystem of organizational processes and supply chain dynamics, thereby contributing to improved operational outcomes and strategic objectives.. For this purpose, the duration of adoption has been categorized into four groups: less than 1 year, between 1 to 3 years, between 3 to 5 years, and more than 5 years. The results from the frequency table indicate that the majority of users (89.8%) have utilized these platforms for more than 1 year, with the highest adoption period being between 1 to 3 years at 35.5%, followed by between 3 to 5 years at 30.8%.

3.2 Impact of ISCPA on time, cost, and risk management

The impact of the Integrated Supply Chains Platform Adoption on time, cost, and risk management variables, the impact of management variables on each other, and their collective influence on the overall performance of ISCP users.

According to the survey, the users of Integrated Supply Chain Platforms have relatively high satisfaction with the implementation of these systems, as most users have assigned responses of 4 (within a 5-Likert rate).

The users of Integrated Supply Chain Management also demonstrated relatively high satisfaction with the improvement of the system's performance in risk management, as most users have assigned responses of 4 to the risk management-related questions.

Along the same line, respondents demonstrated high satisfaction with the improvement of the system's performance in time management and cost management, as most users have assigned responses of 4 to these questions.

3.3 Structural Equation Model

The causality of the conceptual model was assessed. The null hypothesis of noncausality was assessed at the usual 5% significance level, and the results are presented in Table 2. Eight hypotheses, each of which indicates a relationship among two variables, were tested. For example, it was found that Integrated Supply Chain Platform Adoption influences Risk Management at a significance level of 5% by rejecting the null hypothesis H2. On the other hand, the null hypothesis H1 was not rejected, resulting in no causal relationship between the two variables (Integrated Supply Chain Platform Adoption and Cost Management).

Table 2 Causality test results

Null hypothesis	T statistic	p-value	Identified causality
ISCPA does not influence CM	1.186	0.236	
ISCPA does not influence RM	2.241	0.025	ISCPA influence CM
ISCPA does not influence TM	3.029	0.003	ISCPA influence TM
CM does not influence performance	2.128	0.034	CM influence performance
RM does not influence CM	3.348	0.001	RM influence CM
RM does not influence TM	4.335	0.000	RM influence TM
TM does not influence CM	3.977	0.000	TM influence CM
TM does not influence performance	1.177	0.240	

Based on the confirmed causal relationship, a Structural Equation Model including all the associated components (variables and indicators in Fig. 1) was developed, and analysis was performed to explore complex relationships, investigate multiple interactions, and evaluate the connectedness of the entire network (model). Within the context of Structural Equation Modeling terminologies, five variables (Integrated Supply Chain Platform Adoption, Risk Management, Time Management, Cost Management, and performance) correspond to latent variables, and they are graphically enclosed in a circle. Indicators (Q2 - stakeholder engagement and satisfaction, Q4 – lead times for materials) correspond to observed variables, which are defined as a square. Fig. 1 illustrates the overall Structural Equation Model. For estimating the path coefficients, the algorithm iteratively adjusts them to make the model's predicted covariance matrix as close as possible to the observed covariance matrix derived from your data. This involves calculating the derivative of the likelihood function with respect to each parameter and solving these equations to find the parameter values that maximize the likelihood and minimize discrepancy. The widely-used program IBM SPSS version 26 was used for the implementation.

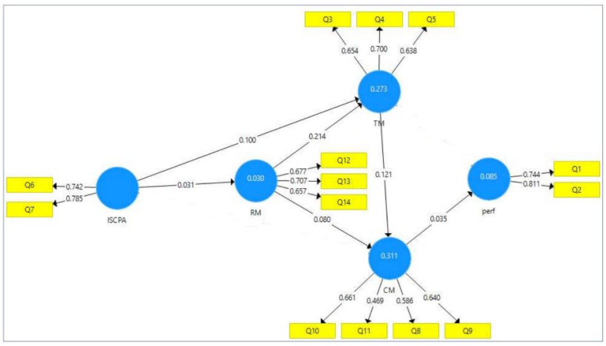

Figure 1. Structural Equation Model Analysis

Analyzing the results of the Structural Equation Model based on the standardized path coefficient (0.742 between Q6 - Reduction in Order Errors and Integrated Supply Chain Platform Adoption in Fig. 1) led to the following two observations. First, the trends of the five variables (i.e., Integrated Supply Chain Platform Adoption, Time Management, Risk Management, Cost Management, and Performance) presented in Fig. 1 align with the results of the Structural Equation Modelling. For example, a standardized path coefficient of 0.87 implies that Risk Management is strengthened as the Integrated Supply Chain Platform Adoption increases. Second, three Cost Management metrics (Q8, Q9, and Q11) and one Time Management metric (Q5) were found to have insignificant relationships, as represented by low standardized path coefficients (0.586, 0.640, and 0.469, respectively) and (0.638). In our study, the cutoff criterion was set to 0.65 (standardized path coefficients lower than 0.65 represent an insignificant relationship). Consequently, Cost Management is driven by a scheduled budget, which is critical for the financing of the project (line of credit) while time management is driven by the lead times for materials.

The study model investigates the impact of implementing the Integrated Supply Chain Platform Adoption system on users' projects and its role in the intermediary variables of management (cost, and risk management). Subsequently, the role of management variables on the overall project performance was evaluated. To analyze the final structural equation model, two stages must be considered.

Firstly, measurement models need to be examined, and the quality and appropriateness of indicators in fitting variables should be assessed. In the next stage, the fit of structural equations in the final model was assessed. By examining fit indices, validity, and reliability of the final model, the appropriateness and accuracy of the model fit will be assessed.

After drawing the structural equation model and estimating regression coefficients, the results of fitting the proposed structural equation model, separated by variables, are as follows.

The factor loadings related to the studied constructs were examined. If these values exceed the critical value of 0.4, it indicates the appropriateness of the item (the question in question) in measuring the latent variable. As observed, appropriate values for standardized factor loadings have been obtained for all constructs, and all considered items in the structural equation model.

In the Integrated Supply Chain Platform Adoption, the factor loadings for order errors and unnecessary supply chain processes (0.742 and 0.785) have been included in the model considering that both demonstrated p-values<0.05.

There were also three controlling variables for the Integrated Supply Chain Platform Adoption, such as the time of adaptation, the size of the projects, and the experience level of the project team that performed factor loadings (0.654, 0.7, and 0.638) with p-values<0.05.

4 Discussion and Conclusions

The previous studies on Enterprise Resource Planning systems in general were mainly focused on customizations and selecting the proper modules for each firm. To advance construction supply chain management, this study focused on the impact of integrated supply chain platform adoption on the performance of construction projects. The main findings of this study can be summarized as follows:

- The study found no significant differences in software system perception among different groups from two northern European countries, regardless of the country or project firm size.
- Information systems are considered commodities, leading to similar benefits across different project sizes and firm scales.
- Longer use of software systems in organizations leads to greater positive impacts on construction risk and time management.

- Introducing new methods and changing routines in firms require time to be effectively implemented, especially with integrated systems that require collaboration across various company functions.
- Adopting supply chain software positively influences risk management in the construction industry by integrating functions such as engineering, procurement, logistics, and finance.
- Integrated software platforms help construction project managers control supply chains, mitigate risks, and improve time and cost management.
- The Integrated Supply Chain Platform Adoption improves time management through better procurement and delivery control, but it does not directly influence cost management.
- Time management, influenced by the integrated platform adoption, indirectly affects overall project performance through cost management.
- The construction industry's reliance on commodified goods means the integrated platform helps manage failed deliveries and source alternatives, though this does not directly reduce costs or construction times.
- Overall, the Integrated Supply Chain Platform Adoption indirectly leads to better project performance through improved time and risk management, subsequently enhancing cost management.

Based on the findings from the current study, several directions for future research can be outlined to expand understanding and application in the field. First, further research should aim to include a more diverse geographic sample to explore whether the observed consensus extends globally. Second, as the study suggests that longer adaptation periods for software systems result in more significant benefits, future research could track organizations over time to document the progression of impacts on risk, time, and cost management, offering a more detailed understanding of the adaptation process. Third, as technology evolves rapidly, future studies should consider the impact of new software solutions, such as artificial intelligence and blockchain, on supply chain management, risk mitigation, and project performance in the construction industry. Lastly, exploring the comparative effectiveness of different supply chain management software solutions could help identify key features and practices that drive success in risk, time, and cost management.

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