Supply Chain Process Integration Capability and Project Outcomes: The Interplay of Supply Chain Visibility and Project Complexity

Mohammed Ali Aldossary, Department of Management, School of Business, King Faisal University, Al-hasa, Saudi Arabia.
Email: maaldossary@kfu.edu.sa

Shishi Kumar Piaralal, Director, Open University Malaysia, Menara OUM, Block C, Kelana Centre Point, Kelana Jaya, Malaysia.
Email: shishi@oum.edu.my

Corresponding Author: Mohammed Ali Aldossary, Email: maaldossary@kfu.edu.sa

ABSTRACT

This study explores how supply chain process integration capability (SCPIC) influences construction project performance (PP), with a focus on the mediating effect of supply chain visibility (SCV) and the moderating role of project complexity (PC). The goal is to deepen understanding of how integrated supply chain capabilities can drive improved project outcomes within the dynamic context of the construction industry.A quantitative, cross-sectional research design was adopted, collecting data from 235 construction employees. Established and validated measurement instruments from prior research were utilized. The relationships among variables were analyzed using variance-based structural equation modeling via ADANCO software, assessing both measurement and structural models to evaluate direct, mediating, and moderating effects.The analysis revealed that SCPIC has a significant positive effect on PP. Moreover, SCV exhibited a direct positive influence and served as a significant mediator between integration capability and performance, emphasizing its importance in facilitating real-time coordination and decision-making. The moderating analysis further indicated that PC strengthens the positive relationship between SCPIC and PP, suggesting that integration capabilities yield greater performance benefits in highly complex project environments.Grounded in the Resource-Based View (RBV) and Dynamic Capabilities Theory (DCT), this study contributes to theory by identifying SCV as a dynamic mediating capability and PC as a contextual moderator. From a practical standpoint, the findings provide valuable guidance for construction organizations, encouraging them to build more integrated, transparent, and adaptive supply chain systems to enhance overall project performance.

Keywords: Supply Chain Integration, Supply Chain Visibility, Project Performance, Project Complexity, Construction Industry

INTRODUCTION

The construction sector is a crucial component of the economic growth and development of infrastructure although it is plagued with the constant problems of overruns, schedule slippage, coordination problems, and low productivity (Kuoribo et al., 2022). These issues are usually caused by fragmented construction supply chains with numerous stakeholders, unstable project conditions, and strong interdependence of different functions and organizations (Datta et al., 2023). In an attempt to counter these issues, supply chain management (SCM) has become even more significant as a method of improving the performance of projects as well as the general efficiency in the construction industry (Long et al., 2022). The primary attributes of SCM are the process integration and cooperation between the participants of a project, which are the determinants of the excellence of the operational processes (Wang & Feng, 2022). The capability of supply chain process integration is the capacity of a firm to align financial, physical, and information flows to its partners in order to guarantee the easy allocation of resources, scheduling as well as decision-making (Abdelilah et al., 2021). This is an especially essential feature in construction projects as the efficient communication, the timely delivery of materials, and quick decision-making play a direct role in determining the performance results (Jiang et al., 2023). With the growing complexity of the present-day construction projects, the necessity of integrated systems that encourage transparency and coordination of all the stages of the project under consideration has never been as pressing as it is now (Cheung & Ma, 2025).

Experimental data always indicate that the high levels of supply chain process integration have a positive impact on the project performance in both construction and manufacturing scenarios (Su et al., 2025). The effectiveness of material, financial, and informational flows improves the work of contractors, suppliers, and clients and results in better cost management, time management, and quality of the project (Lafhaj et al., 2024). As an example, information systems integration helps to establish timely communication and minimize uncertainty in the project implementation process, whereas financial and physical flow integration ensures that delays in procurement and cash flow are minimized, as mentioned (Wang et al., 2022). Additionally, digital technologies like Building Information Modeling (BIM) and Enterprise Resource Planning (ERP) systems enhance integration because they provide the opportunity to see and communicate with geographically separated teams in real-time (Kamble et al., 2021). Such a phenomenon as supply chain visibility (SCV) has also become one of the key factors of project success because it enables project stakeholders to monitor the processes, predict failures, and act in advance (Mohd Tarli, 2017). Together, the literature highlights that the rationalization of integration ability and visibility enhance better performance results, particularly in multi-faceted and interdependent construction settings.

Although many efforts have been made to explain how supply chain integration can be applied to enhance the performance of construction projects, there are still some important gaps in the literature (Rai et al., 2006). Previous researches have been considering supply chain integration as one-dimensional concept without considering individual role of financial, physical, and information flow integration (Xi et al., 2022). Such a conceptualization does not provide much insight into the unique role of various components of integration in project outcomes (Musarat et al., 2024). Furthermore, empirical research tends to concentrate on the general industrial supply chains, and relatively fewer studies specifically investigate integration in the construction industry where temporary collaborations, project-based operation, and contractual relationships are the peculiarities of the field (Ominde et al., 2024; Unegbu et al., 2023; Van Tam et al., 2021). Also, as much as SCV has been recognized as a major enabler of coordination, its mediating ability in transforming integration capabilities to PP has not been thoroughly explored (Tiwari et al., 2024). Most of the studies are inclined to consider visibility as a result of integration as opposed to a process that brings about performance gains through integration (Al Tera et al., 2024; Baycik, 2024; Tan et al., 2022). This has a theoretical vacuum in the explanations of the effects of information transparency in converting internal coordination efforts into project deliverables.

The other large gap is that of the role of PC as a moderator especially in its impact on the strength of the integration-performance relationship. Construction projects are very different in terms of the level of technology used and the structure of organizations, which also affect the work of integration capabilities (Kunkcu et al., 2025). The significance of information and process integration can be enhanced by high rates of technological complexity including the use of state-of-the-art digital equipment or novel construction methods, whereas coordination difficulties could be enhanced by organizational complexity caused by multiple contractors, consultants, and suppliers (Ominde et al., 2024). There is however scarce empirical evidence on how integration capabilities perform equally at various levels of complexity. Although prior studies have demonstrated a positive relationship between supply chain integration and project success, few have simultaneously examined both mediating and moderating factors within a single framework that captures the dynamic and context-specific nature of construction projects. This highlights the need for a more comprehensive investigation that not only explores direct relationships but also considers the conditional and indirect mechanisms through which supply chain capabilities influence project outcomes.

Accordingly, the present research seeks to analyze the impact of supply chain process integration capability (SCPIC) on construction project performance (PP), while integrating the mediating influence of supply chain visibility (SCV) and the moderating role of project complexity (PC). The study's specific objectives are to:

- Evaluate the relationship between SCPIC and PP.
- Determine the direct effect of SCV on PP.
- Explore the mediating role of SCV in the relationship between SCPIC and PP.
- Examine the moderating impact of PC—particularly technological and organizational complexity—on the link between SCPIC and PP.

LITERATURE REVIEW

The construction industry is characterized by special operational complexity as it is a project-oriented industry with a fragmented stakeholder ecosystem and the reliance on the external environment, which predetermines the fact that seamless integration of supply chain processes is the key to the efficiency and performance results under the conditions of the industry (Nguyen et al., 2025). The classic construction supply chains are usually typified by silo operations, few information sharing and workflows, which result in delays, cost overruns, material wastage and quality quarrels (Princes & Said, 2022). With the increasing intensity of competition and changes in project delivery expectations, organizations are laying stress on capability of process integration i.e. the capacity to align the processes of planning, procurement, logistics and information systems between the contractors, suppliers, consultants and clients (Salazar et al., 2024). According to the previous research, high-level integration enhances not only the visibility and responsiveness but also the trust, coordination, and collaborative decision-making among the partners (Abdullah et al., 2025). It also allows real-time interaction, coordinated time, curbing risks and better resource allocation, which consequently minimizes uncertainties and eliminates the repetitive process of rework (Salazar et al., 2024). Moreover, strategic integration builds on long term relationship and knowledge sharing and enables firms to cease transactional relations to value co-creation and innovation at project lifecycle stages.

Integrating internal and external processes is also regarded as an emerging dynamic capability that influences strategic agility and operational resilience of construction projects (Zhang et al., 2023). Researchers suggest that firms that have efficient integration systems like common digital systems, standardized work processes, and collaborative performance reviews can achieve better performance results of their projects in terms of durability, costs, quality, and customer satisfaction (Datta et al., 2023; Omrany et al., 2023). The integration also triggers the lean project delivery processes and this leads to minimized wastage, maximized productivity and increased flexibility to any unexpected changes in the market or design (Wang & Feng, 2022). In addition, in case integration is spread throughout the supply chain, the concept facilitates proactive risk management, as it allows the disruption to be identified early and also corrective measures to be taken quickly (Cui et al., 2022). The empirical research points out that companies investing in technological facilitators such as Building Information Modeling (BIM), cloud based project management, and collaborative procurement systems are better in aligning on-site operations with off-site activity in the supply chain (Tan et al., 2022). Finally, an effective supply chain will be associated with strategic competitiveness through enhancing predictability of projects, inter-firm cooperation, and repeat partnering which are major attributes that determine success in the construction industry on the long-term.

Hypothesis Development

SCPIC refers to the extent to which firms coordinate and align the flow of resources, activities, and decision-making across their supply chain partners (Lin & Fan, 2024). It includes the financial flow integration, whereby there is smooth flow of capital and synchronization of payments among the stakeholders; physical flow integration whereby there is coordination of procurement and delivery of materials and equipment as well as information flow integration whereby real-time operational information, schedules, forecasts and design updates are shared among the project participants (Abdelilah et al., 2021). Previous investigations have established that incomplete financial processes, ineffective logistics activities, and substandard information visibility are some of the leading factors that lead to delays, cost escalation, and re-work in construction projects (Mohd Tarli, 2017). It has been discovered that the better financial, material and information flows are handled in an integrated way, the better coordination, diminishing risk and quicker reaction to uncertainties is achieved by the project team (AlMahri et al., 2025). As an example, financial integration will enhance trust and minimize disagreements, physical flow synchronization will reduce material waste and logistic delays, and the transparency of information will enrich the decision-making process and shared planning at the different stages of the project (Kermanshachi et al., 2021).

The empirical data demonstrates the beneficial effect of supply chain integration on the PP significantly in the construction project where inter-organizational and cross-functional cooperation is crucial (Cui et al., 2022). Research has shown that projects with a high degree of coordinated financial flow, synchronized material drop to the sites and open communication systems in real time have a much better performance when it comes to cost efficiency, schedule compliance, quality performance, and satisfaction among stakeholders (Vargas Esperon, 2023). Scientists believe that a combination of these integration capabilities produces a harmonized working environment in which uncertainties are eliminated at the earliest stage possible, bottlenecks in the operational system are reduced, and the distribution of resources is optimized (Oubrahim et al., 2023). This is in line with the concept of dynamic capability theory, which connotes that the integrated process capabilities can help firms to be adaptable to the project complexities and the external disruptions (Wang et al., 2022). Therefore, it is hypothesized that SCPIC with the integration of financial, physical, and information flows can have a significant positive effect on the performance of construction projects based on strong empirical evidence and theoretical arguments.

H1: SCPIC has significant impact on PP

SCV is the degree to which the stakeholders of the project can get access to accurate, real-time, and end-to-end data about supply chain operations, such as status of materials, inventory balances, delivery dates, financial activities, and risk notifications (Emon & Khan, 2024). It will allow the stakeholders to observe how resources and information are flowing within the entire project network, increasing transparency and reliability in decision-making (Khan et al., 2024). Visibility is very important in construction projects where the level of uncertainty and interdependence among project players is high and it helps to reduce operational risks as well as to avoid disruptions (Swink et al., 2023). Literature indicates that low visibility usually results in shortages of materials, miscommunication, rework, and unexpected delays, whilst high visibility enables companies to prepare in advance about potential bottlenecks, plan, and coordinate proactively and have a smooth flow between the planning and execution stages (Kalaiarasan et al., 2022). Scientists lay stress on the fact that digital technologies (BIM, IoT, ERP, real-time tracking systems) make a tremendous contribution to visibility, since they give all participants of the supply chain a common data platform (Al Tera et al., 2024).

Empirical literature always documents that good SCV enhances the essential project results regarding cost-effectiveness, reliability of the schedule, quality performance, and satisfaction of the stakeholders (Jain et al., 2024). Greater visibility also enables the project managers to make sound decisions, minimize variability in lead times as well as make the forecasting and resource allocation more precise (Mohd Tarli, 2017). Previous studies have demonstrated that the higher the transparency of their supply chain operations, the more firms have reduced disruption, reduced time on problem solving, as well as increased coordination among contractors, suppliers, and clients (AlMahri et al., 2025; Messina et al., 2022; Tiwari et al., 2024). In addition, visibility enhances trust and partnership among the partners and reduces conflicts and optimizes responsiveness to unexpected design or market changes (Tan et al., 2022). Based on these empirical results, it is rational to say that when the supply chain becomes more visible, the monitoring becomes more effective, the corrective measures are faster, and all the parties involved in the project are directed at the shared performance objectives.

H2: SCV has significant impact on PP

SCPIC allows the integration of the financial, physical and information flows between the project stakeholders, but the effectiveness of this process can be optimised better when SCV is high (Tan et al., 2022). Integration provides the structural base on which connectivity among systems is developed and yet in the absence of real-time transparency, stakeholders would still face delayed risk detection, information gap or mismatched responses (Al Tera et al., 2024). Researchers underscore that integration enables the establishment of common platforms, common communication protocols and data synchronization systems that, naturally, improves visibility through the supply chain (Oubrahim et al., 2023). It has been established in previous literature that despite the existence of integration, in case of weak visibility, there are operational blind spots and reactive decision-making, whereas in situations of strong integration and higher visibility, the project activities are performed in a proactive fashion, coordinated and informed, and efficiently (Abdelilah et al., 2021).

It has been empirically found out that visibility is a bridging process that transforms the integration benefits to the performance change that can be measured (Kalaiarasan et al., 2022). Visibility enables the project teams to track the movement of materials, financial position, and the logistic position in real time to enable the teams anticipate disruption, overcome bottlenecks beforehand, and efficiently allocate resources (Khan et al., 2024). It has been noted that the best construction projects are not only very much integrated but also transparent that will allow stakeholders to work together in responding to arising issues (Baycik, 2024). Visibility enhances the beneficial effects of integration in terms of costs, time, and quality performance by increasing the level of clarity, lessening the degree of uncertainty, and ensuring a collective situational awareness.

H3: SCV mediates the relationship between SCPIC and PP

The concept of PC is the level of the difficulty of controlling different technological and organizational factors in a construction project (Cheung & Ma, 2025). Technological complexity is due to the complexity of design, application of sophisticated tools, adoption of digital technologies, and technical dependencies of the elements in the project (Bakhshi et al., 2024). In its turn, organizational complexity is caused by the number of stakeholders, the variety of roles and responsibilities, the degree of contractual interdependence, and the amount of coordination that needs to be done between a variety of teams (Vargas Esperon, 2023). The complexity of the project is normally accompanied by uncertainty, and the risk of miscommunication is also enhanced, and the need to coordinate the decisions and act-in-real-time is also intensified (Princes & Said, 2022). Researchers have pointed out that with the increasing complexity of the projects, the importance of the integrated supply chain mechanisms has been of growing significance to the synchronization of financial, material, and information flows (Nguyen et al., 2025).

Previous research shows that the capability of supply chain process integration tends to lead to better performance of projects although the extent of the association differs with the degree of complexity of projects (Ominde et al., 2024). In tremendously complicated projects, integration activities should extend past straightforward coordination and encompass more complex systems that aid joint planning, real time adoptions, and responsive resource distribution (Yadav & Paul, 2023). At low complexity even moderate degrees of integration can be adequate to sustain performance. Nevertheless, when integrational complexity is great, both the worth of integration and the influence of interdependence become much more pronounced, whereas reducing risks and increasing adaptability are among the issues that can be addressed (Jia et al., 2023). On the other hand, in an extremely complicated environment where there is weak integration, performance becomes more drastic because there is misalignment and slowness in responses.

H4: PC moderates the relationship between SCPIC and PP

Theoretical Framework Supporting the Research

The DCT and RBV offer a formidable theoretical base upon which the relationship hypotheses at this model can be explained. RBV states that companies get better performance in case they create distinct, useful and inimitable capabilities in the form of SCPIC which enables smooth coordination of the financial, physical and informational flows among the stakeholders, which increases project efficiency and performance (Barney, 2001; Wernerfelt, 1984). Nevertheless, RBV only presupposes the relatively stable environments, and construction projects exist in the context of extremely dynamic and uncertain one, and this is where the DCT may be more applicable. According to this theory, firms should not just have valuable resources, but continually restructure them and reengineer them to respond to the fast changing conditions of the project in order to maintain performance (Teece et al., 1997). SCV is an adaptive dynamic capability that supports real-time monitoring, transparency, and proactive response, hence mediating the channel through which the integration capabilities are converted to the PPs. Also, complexity of the project (technological, organizational) is the contingency factor which results in the strength of integration impact, as complex projects require more sophisticated integration processes to be coordinated. Thus, the combination of the RBV and DCT knowledge justifies why the capability of supply chain process integration affects the PP, why the impact of this effect is enhanced by the presence of SCV, and why PC modifies the quality of the association between the two. The theorized relationships among these constructs are represented in Figure 1.

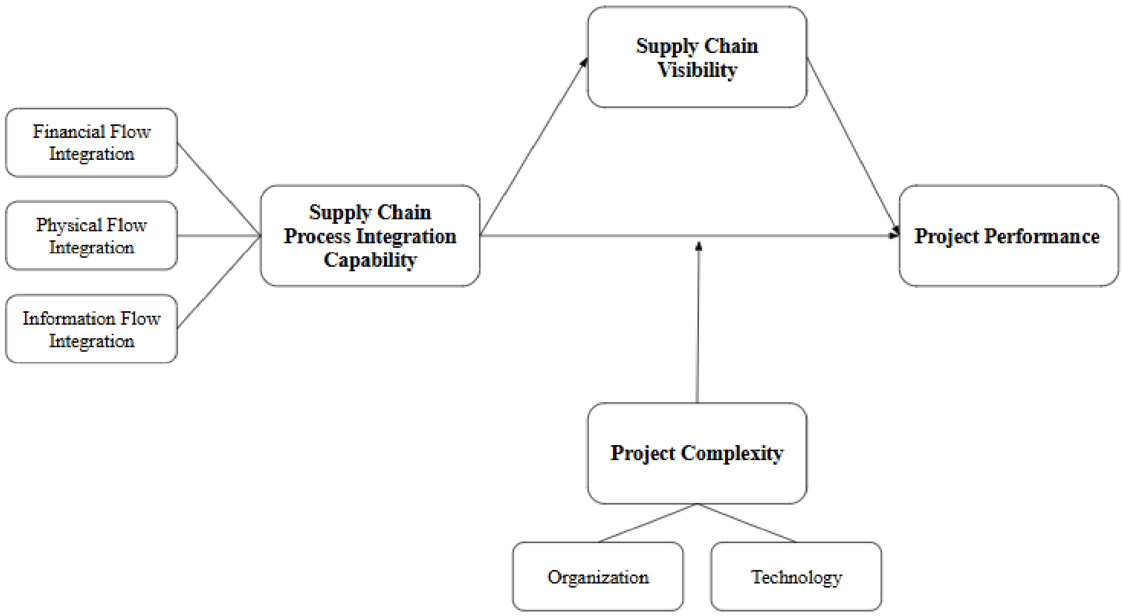

Figure 1: Conceptual Framework

METHODOLOGY

This study used the quantitative and cross-sectional research design to empirically investigate the association between supply chain process integration capability (SCPIC), supply chain visibility (SCV), project complexity (PC), and project performance (PP) in the construction sector. This was considered to be a good approach because it will be possible to test various hypothesized relationships simultaneously using a structural equation modeling (SEM). The aim was to examine both the direct and indirect impacts of financial, physical, and information flow integration on PP, where SCV is referred to as a mediator and PC is referred to as a moderator. The design is in line with past empirical studies on supply chain and construction management where quantitative methods are usually employed to determine the cause-and-effect relationships between the operational and strategic variables (Hair & Alamer, 2022).

The target population was the employees working in construction projects environment and sample comprised the project managers, engineers, procurement officers and the supply chain specialists. The sampled participants were selected because of their direct role in the implementation of the projects, coordination, as well as the decision-making process, therefore they were the appropriate respondents in the measurement of the integration construct and performance construct. The obtained valid responses were 235 in amount. The sample size was considered sufficient enough to apply partial least squares structural equation modeling (PLS-SEM) that requires a minimum of ten paths per construct (Hair et al., 2021). The stratified random sampling was chosen in order to make the sample representatives proportional to the participants of various project positions and levels of organizations.

The scales used in the measurement of the present study were carried into other research instruments that had been tested before to obtain content and reliability. The PC scale was modified following the (Princes & Said, 2022) and consisted of four items of two dimensions: technological (2 items) and organizational (2 items). The scale of SCV was determined using a seven-item scale created by Mohd Tarli (2017), which measures the extent to which the participants of the project have access to real-time information throughout the supply chain operations. The operationalization of SCPIC involved three dimensions, which were modified to fit the study by Rai et al. (2006): financial flow integration (2 items), physical flow integration (4 items), and information flow integration (5 items). Ten items selected based on the (Unegbu et al., 2022) study were used as the measures of PP and included several areas of construction performance, such as cost, time, quality, client satisfaction, and overall efficiency.

The data was obtained via a self-administered structured questionnaire (both electronically and in paper formats) that was sent to the targeted respondents in construction firms. The survey questionnaire was developed on the basis of Google Forms and was distributed in the professional circles, as well as the industry associations and LinkedIn groups dedicated to the sphere of construction and supply chain management. To guarantee adequate response rate the data collection took a period of two months. Prior to the collection of the data, the questionnaire was tested on 20 professionals, in order to check the clarity and the suitability of the wording. There were minor changes applied to increase the readability of some items, especially those that involved technological integration and visibility. The pilot test responses were not included in the final analysis.

ADANCO software which applies the variance-based structural equation modeling (SEM) was used to analyze the data. This software has been chosen because it is effective in handling the complex hierarchical constructs as well as measuring and evaluating the measurement and structural models at the same time. There were two stages of the analysis. The measurement model in the first stage was accepted to be reliable and valid as it represented the rho (rhoA) of DijkstraHenselers, composite reliability of the model (CR), Cronbaches alpha (alpha), and average variance extracted (AVE). The Heterotrait-Monotrait ratio (HTMT) (as recommended by Henseler et al., 2015) was used as the additional method to establish the discriminant validity. The second phase involved the analysis of the structural model in order to test the hypothesized relationships of the variables. The 5,000 resamples were used in bootstrapping to receive the path coefficients, t-statistics, as well as the p-values that identified whether the relationships were significant or not. The quality of the models was evaluated based on the explanatory (R 2) and predictive (Q 2) values, whereas the quality of model quality was verified using the root mean square error (RMSE) and mean absolute error (MAE) indices.

The measurement model was very reliable and valid in all the constructs. The reliability coefficients of all were above the required level of 0.70, and the values of AVE were above 0.50, which proved the convergent validity (Hair et al., 2021). The ratios of HTMT were lower than 0.90 which means that there is satisfactory discriminant validity and empirical distinction between the constructs. Generally, results of reliability and validity established that the contextualized measurement scales were suitable and statistically sound to be used in field of Saudi construction industry.

RESULTS

The results of the reliability and validity test of all study constructs are summarized in Table 1. They all obtained values of Dijkstra-Henseler rho, Joreskog composite reliability and Cronbach alpha (a) are above the 0.70 mark, which indicates satisfactory internal consistency reliability (Hair Jr et al., 2021). It is important to note that the SCV and PP have the highest reliability scores with both being above 0.90 which means that their measurement items are highly stable. Besides this, AVE values of all constructs are above 0.50, which is the level of convergent validity acceptable as suggested by Fornell and Larcker (1981). The example of the AVE scores of 0.725 organizational factors and 0.678 technological factors, shows that more than 67 percent of the variance is captured by the related indicators. In general, the results prove the fact that all the constructs used in the study are sufficiently reliable and convergent valid, which proves the validity of the measurement model.

The proposed structural model is estimated in Figure 2 and shows the proposed relationships between the capability of supply chain process integration, SCV, PC, and PP. The graphical analysis supports the statistical value of all direct, mediating, and moderating effect, as all are in line with the theoretical assumptions formulated previously. The magnitude and direction of the path coefficients are a positive and significant impact of the integration capability and visibility to PP, which aligns with the results of previous researchers regarding the significance of integrative and information-intensive supply chain strategies in construction. The model effectively shows a properly organized causal flow, which confirms the overall structure that was experimented in this paper.

Table 1: Variables reliability and validity

	Dijkstra-Henseler's rho (ρA)	Jöreskog's rho (ρc)	Cronbach's alpha(α)	Average variance extracted (AVE)
Technology	0.808	0.808	0.808	0.678
Organization	0.843	0.841	0.839	0.725
Supply Chain Visibility	0.939	0.936	0.937	0.677
Financial Flow Integration	0.760	0.755	0.752	0.607
Physical Flow Integration	0.836	0.829	0.830	0.550
Information Flow Integration	0.900	0.898	0.898	0.639
Project Performance	0.920	0.916	0.917	0.524

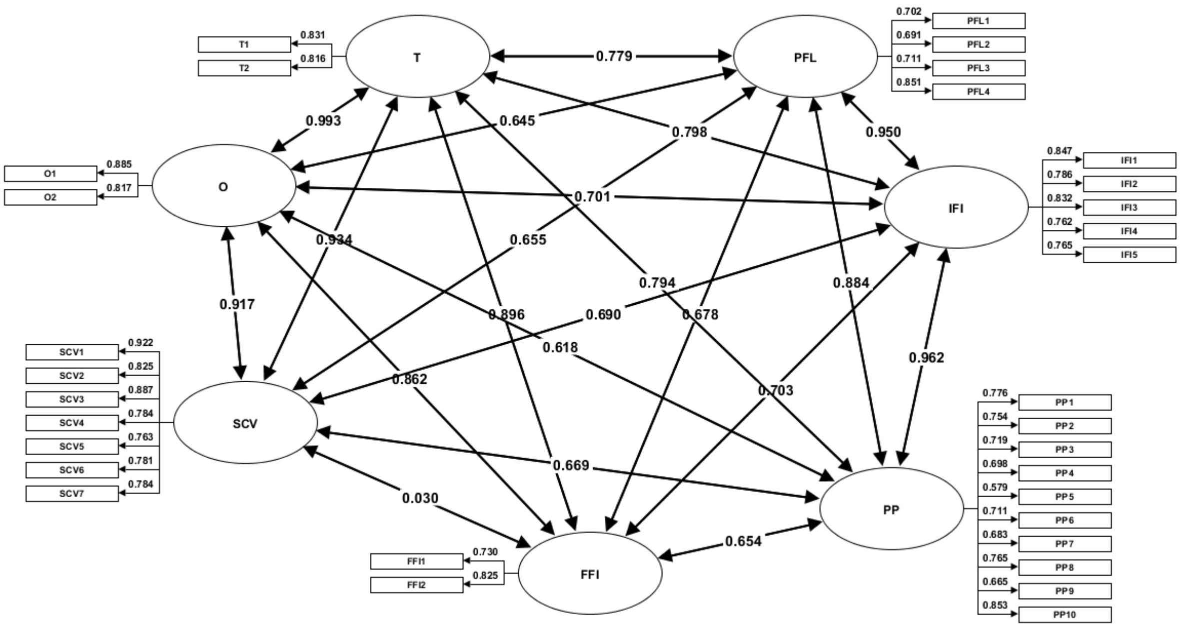

Figure 2: Estimated Model

Table 2 shows the confirmatory factor analysis (CFA) which exhibits factor loading of all the indicators in the constructs. Everything has a high loading on its constructs, and factor loading is more than the desired value of 0.70 that is recommended by Hair et al. (2021). The loading of technology (T1 = 0.831, T2 = 0.816) and organization (O1 = 0.885, O2 = 0.817) is large, which means that the constructs are represented. The SCV has strong loadings of between seven items with their range of 0.763 to 0.922 and this supports the precision and multidimensional operationalization of SCV. Likewise, all the indicators of financial, physical, and information flow integration have sufficient loading values with the IFI1 and IFI3 having especially powerful values (0.847 and 0.832). The range of PP items is between 0.579 and 0.853, which means that the performance dimensions are represented reliably. In general, the CFA outcomes are in favor of good indicators reliability and construct validity.

Table 2: Confirmatory Factor Analysis

Indicator	Technology	Organization	Supply Chain Visibility	Financial Flow Integration	Physical Flow Integration	Information Flow Integration	Project Performance
T1	0.831						
T2	0.816						
O1		0.885					
O2		0.817					
SCV1			0.922				
SCV2			0.826				
SCV3			0.887				
SCV4			0.784				
SCV5			0.763				
SCV6			0.781				
SCV7			0.784				
FFI1				0.730			
FFI2				0.825			
PFL1					0.702		
PFL2					0.691		
PFL3					0.711		
PFL4					0.851		
IFI1						0.847	
IFI2						0.786	
IFI3						0.832	
IFI4						0.762	
IFI5						0.765	
PP1							0.776
PP2							0.754
PP3							0.720
PP4							0.698
PP5							0.579
PP6							0.711
PP7							0.683
PP8							0.765
PP9							0.665
PP10							0.853

Table 3 indicates the Heterotrait -Monomethod Heterotrait -Monomethod (HTMT) values to determine discriminant validity. The values of all HTMT are less than the maximum of 0.90 suggested by Henseler et al. (2014), which proves that all constructs are different in the concepts of each other. As an illustration, the value of HTMT between the technology and organization is 0.794, whereas the value between the SCV and financial flow integration is 0.703, which proves to be sufficient to discriminate between the two variables. The maximum value of HTMT lies between the PP and physical flow integration (0.883) that is acceptable. These findings confirm that there is no problem of multicollinearity and that the constructs have a unique contribution to the explanation of the structural model. Thus, discriminant validity has been achieved in the study in terms of all constructs.

Table 3: Discriminant Validity (HTMT)

Construct	T	O	SCV	FFI	PFL	IFI	PP
Technology							
Organization	0.794						
Supply Chain Visibility	0.729	0.815					
Financial Flow Integration	0.700	0.816	7.032				
Physical Flow Integration	0.775	0.641	0.643	0.667			
Information Flow Integration	0.795	0.701	0.689	0.703	0.748		
Project Performance	0.789	0.613	0.661	0.653	0.883	0.816	

The values of R-Square, adjusted R-Square, predictive relevance (Q 2 predict), and the model fit indices (RMSE, MAE) are indicated in Table 4. Both endogenous constructs have higher explanatory power of 0.614 and 0.891 indicated in the R-square values of SCV and PP respectively. These values show that the variance of SCV and PP is explained by the independent variables at 61 and 89 percent respectively, which implies a high degree of model adequacy. The adjusted R-Squares nearly match, and this denotes stability in the capability of the model in explaining the number of predictors. The measures of predictive relevance, i.e., the values of Q2predict are larger than 0.35, as it is recommended by Hair and Alamer (2022), with 0.421 and 0.672 being the predictive relevance of SCV and PP, respectively. Also, the low value of RMSE and MAE represents the low number of errors in prediction and a good fit of the model. All these statistics affirm the model of analyzing the relationships between variables as having a high degree of predictive accuracy and reliability.

Table 4: R-square statistics Model Goodness of Fit Statistics

Construct	Coefficient of determination (R2)	Adjusted R2	Q^2predict	RMSE	MAE
Supply Chain Visibility	0.614	0.612	0.421	0.386	0.298
Project Performance	0.891	0.889	0.672	0.245	0.187

The test structure model and the path analysis of the hypothesis is graphically presented in Figure 3. It demonstrates the direct, mediating, and moderating associations between the significant constructs of SCPIC, SCV, PC, and PP. The graphical representation validates that all of the hypothesized paths are positive and significant which validates the conceptual framework formulated above. This aspect shows that integration capability not only increases the performance of the project, but also has an indirect impact, therefore its dual impact. The moderating effect of PC can also be observed since the magnitude of the integration-performance relationship is stronger when the conditions of the project are of higher complexity. The good path coefficients and clarity of the model indicate that it has good theoretical alignment with the RBV and the Dynamic Capabilities perspectives (Barney, 2001;

Teece et al., 1997). Therefore, the structural model validates both the theoretical rationale and empirical robustness of the study framework.

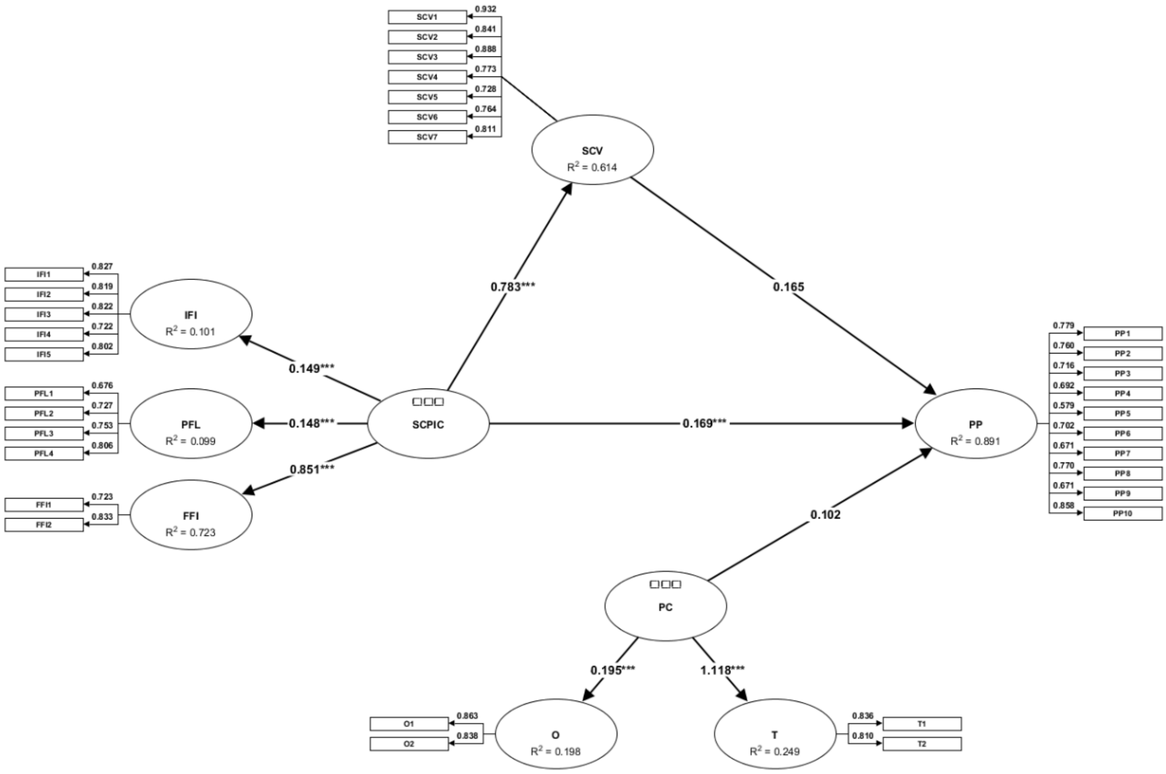

Figure 3: Structural Model for Path Analysis

Table 5 presents the results of the path analysis conducted to examine the hypothesized relationships among the study variables. All hypotheses were supported, as indicated by t-values greater than 1.96 and p-values less than 0.05. The first relationship ($\beta = 0.169$, $t = 14.257$, $p < 0.001$) shows a strong positive link between SCPIC and PP, indicating that greater integration capability enhances cost efficiency, quality outcomes, and schedule adherence. The second hypothesis was also confirmed, with SCV having a significant yet modest positive effect on PP ($\beta = 0.165$, $t = 2.910$, $p < 0.05$), emphasizing that visibility contributes to improved coordination and responsiveness, in line with previous findings. The mediation test (H3) revealed a significant indirect effect ($\beta = 0.128$, $t = 3.556$, $p < 0.001$), confirming that SCV mediates the relationship between SCPIC and PP, meaning that better visibility transforms integration capability into enhanced project outcomes. The moderation test (H4) also showed a significant effect of PC ($\beta = 0.097$, $t = 3.344$, $p < 0.001$), indicating that the positive influence of SCPIC on PP is amplified in projects with higher technological and organizational complexity.

Table 5: Path Analysis

Hypothesis	Coefficients	Standard Errors	t-values	p-values
H1: SCPIC has a significant impact on PP	0.169	0.011	14.257	0.000
H2: SCV has a significant impact on PP	0.165	0.181	2.910	0.002
H3: SCV mediates the relationship between SCPIC and PP	0.128	0.036	3.556	0.000
H4: PC moderates the relationship between SCPIC and PP	0.097	0.029	3.344	0.001

DISCUSSION

The construction sector is a business that is characterized by uncertainty, interdependence and dynamic stakeholder interaction where the quality of supply chain activities is usually used to measure the success or failure of a project. In this situation, it would be important to the researcher and practitioners to understand the interaction of internal capabilities and external enablers in determining performance. The current paper is relevant in this discussion because it provides an empirical study of the strategic significance of SCPIC, SCV, and PC in forming the project results. The study extends beyond the linear relationships because it measures a strict framework that considers the mediating and moderating mechanisms so as to learn to transform integration-based capabilities in translating them into performance gains in various conditions of the project. The findings are then interpreted in the discussion below through the available literature, and offers theoretical and practical implications and a subtle understanding of operational dynamics of the modern construction supply chain.

This research findings gave a solid empirical support to the validity of the positive effects of SCPIC in the performance of construction projects through the first hypothesis. The findings suggest that a well-coordinated financial, physical, and information flows are very crucial in improving coordination, efficiency in decision making and optimization of resources at all time during the project lifecycle (Shenhar & Dvir, 2007). These findings align with the previous researchers who have found that higher-level of integration capability leads to better cost management, schedule management, and quality performance in the project. The existing findings support the idea that in case organizations align their financial operations, optimize the flow of materials, and share information in real time, they will be able to mitigate the uncertainty in their operations and respond proactively to disruptions before they turn into significant performance missteps (Ominde et al., 2024). This observation supports the information that the supply chain integration is a strategic operation capability that can assist the construction firms to escape fragmentation and an overall augmentation in the efficiency of project delivery. In line with the RBV, the research confirms the existence of the integration capability as a resource that is valuable and inimitable, which directly causes the high-performance realization of the construction projects.

The second hypothesis that directly tested the impacts of the SCV on the PP was also affirmed and indicated that the visibility of the supply chain is a crucial performance-enhancing factor. The findings indicate that increased visibility enables the stakeholders to be aware of material position, financial obligations, and real-time proceedings along the entire supply chain, allowing interventions to be implemented and combine efforts to correct arising problems (Nguyen et al., 2025). These results are consistent with the existing literature that puts visibility as one of the most important enablers to reduce supply uncertainty, enhance forecasting accuracy, and responsiveness. The approbation of this hypothesis highlights the fact that, visibility is not only a support activity but a fundamental performance engine that enhances trust, transparency and performance agility among the project players. The findings also indicate that even though integration forms the structural base of connectivity, visibility ensures that structural base is fully exploited by effectively using transparency in real-time and proactive decision-making (Yadav & Paul, 2023). As such, the results are relevant to the current literature that has placed SCV as a strategic capability that has a strong direct effect in improving overall performance of construction projects.

The results also supported the third hypothesis and provided SCV as an important mediator variable in the correlation between SCPIC and PP. The findings suggest that although integration capabilities offer the required framework on which the integration process can be coordinated, their performance advantages are better achieved where there is visibility to convert such an integration into operational effectiveness in real-time operational terms (Wang et al., 2022). It is in line with the extent of the prior studies indicating that the visibility improves the capacity of the stakeholders to notice the disruptions at an early stage, better situational awareness, and timely corrective measures. The mediation effect of the current research supports the claim according to which integration does not suffice unless the stakeholders have access to the correct and clear information about financial transactions, material movements, and logistical updates in a timely manner. Visibility hence becomes the facilitating interface that converts the integrated processes into viable performance outcomes (Messina et al., 2022). The finding has led to the current body of work by showing empirically that visibility is not merely a complementary variable, but a vital strategic competency that fills the difference between internal process alignment and external performance realisation in construction supply chains.

The fourth hypothesis was also confirmed that PC moderates the relationship between SCPIC and performance of project significantly. The results show that the positive influence of integration is stronger in the environment of construction industry with greater technological and organizational complexity (Swink et al., 2023). The necessity of well-coordinating mechanisms is even stronger in the projects that are marked by the high level of technologies, multiple stakeholders, and the work interdependence that should be managed by the means of integration. The findings are consistent with the previous research that emphasizes the growing role of collaborative and adaptive skills in complicated project environments. On the other hand, in the low-complexity environment, even the moderate degree of integration can be enough to attain the satisfactory performance results, which proves the contingency of integration effectiveness. The fact that this hypothesis was accepted provides valuable theoretical richness by confirming PC as a condition that puts a limit on the strength of integration in affecting performance (Al Tera et al., 2024). This observation offers a practical observation that construction companies must consider highly-developed integration strategies especially in very complex projects since the payoff of the investments on such capabilities are much greater when the conditions of high complexity are encountered.

The overall findings of all four hypotheses indicate the essence of supply chain integration, and the necessity to view it as a strategic capacity that is increased with the help of visibility and the conditions of PC. The adoption of direct, mediating, and moderating relationships confirms the fact that performance in construction projects is not attained through individual factors but through the combined system of systems, adaptive access to information, and situational preparedness. This holistic view is a more credible insight into the way that firms can shift toward reactive problem-solving to proactive and smart supply chain management. The results support the premise that competitive advantage in construction is not only about the presence of resources but about the potential to connect, foresee, and adapt and create a performance-based and resilient project ecosystem.

IMPLICATIONS

Theoretical implications

The theoretical value of this paper is that it combines both the RBV and the DCT to provide an explanation of how the capability of integrating processes within supply chains increases the performance of projects through SCV, but is conditional upon the complexity of a project. Contrary to the earlier works that looked at integration independently, this study moves the theory forward, showing that integration will never be effective without dynamic and real-time visibility mechanisms, which serve as a mediating capability that will change internal coordination to performance outcomes (Teece et al., 1997). The validation of the PC as the moderating factor also expands the contingency theory in the sense that it empirically proves that the usefulness of integration depends on the context, and it is more significant when technological and organizational complexity is high. This multi-layered conceptual framework has a contribution to the body of literature through a more detailed picture of such interaction between structural and adaptive capabilities to impact performance, which expands the previous simple linear models and provides a theoretically enhanced explanation of the difference in performance in construction project settings.

Practical implications

This research has significant practical implications to the construction companies, project managers, and policy makers who aim at improving the performance of the projects based on strategic supply chain management. The findings indicate that companies must invest in the improvement of process integration (financial, physical, and information flows) in order to enhance coordination, minimize delays, and optimize resource utilization, which is consistent with the industry demands to increase the digitalization of the supply chain and collaboration. Nevertheless, the mediating capability of visibility also demonstrates that the utilization of digital platforms like BIM, ERP, and IoT-based tracking systems should be implemented to allow real-time monitoring, risk management that is predictive and visible communication between all the stakeholders. Moreover, the influential moderating effect of PC suggests that the increased integration and visibility are particularly important to the complex projects that include many stakeholders, new technologies, and high-level interdependence structures. This means that depending on the complexity of the project, managers must focus on the integration and visibility strategies by laying a heavier emphasis on the former with the more complex projects to prevent a breakdown of performance. Such study, therefore, offers practical recommendations of developing smarter, more resilient, and performance-oriented construction supply chains.

LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

Although this study has been highly empirically validated and theoretically based, it has some limitations that can be exploited to continue investigating the topic. First, the research design taken in the study is cross-sectional which records relationships at one time, thus cannot be used to give any long-term causal relationship between integration, visibility, and complexity and the PP. A longitudinal or time-lagged study would be appropriate as future research to determine the way these capabilities change over the various project life cycle stages. Second, the research context is restricted to construction projects and mostly to a specific industry and a regional context, which could limit the extrapolation of the results to other industries, including manufacturing, healthcare, or smart infrastructure development. It would be more competitive to develop the model to cross-industry or international comparisons to increase the level of external validity. Third, although this research focuses on technology and organizational complexity as the dimensions of moderation, further studies may consider other situational factors, including regulatory pressure, digital maturity, cultural alignment, or environmental uncertainties to provide more evidence on the boundary conditions. In addition, the qualitative or mixed-method methodology might be used to reveal deeper, practice-based mechanisms that quantitative models might fail to adequately take into account. Such directions in the future would enhance the knowledge of the dynamic and changing character of the modern supply chain ecosystems.

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