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An Integrated Project Delivery-Based Supply Chain Management for Modular Construction in the Philippines

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ABSTRACT

This study explores the enhancement of Supply Chain Management (SCM) efficiency in the Philippines' modular construction sector through Integrated Project Delivery (IPD). It highlights the critical alignment of SCM success factors with IPD principles, emphasizing the importance of collaboration in modular construction projects. Quantitative analysis via surveys among modular construction professionals assesses IPD's impact on SCM efficiency, uncovering a positive correlation between IPD adoption and compliance with SCM success factors, particularly in larger organizations. This reveals the benefits of early collaboration and shared management practices. The research proposes a comprehensive framework tailored to the Philippine construction industry to optimize SCM efficiency by integrating modular construction with IPD principles. This strategy aims to tackle unique organizational and individual challenges, offering insights for improving SCM practices through IPD. The study paves the way for superior project delivery in developing economies and calls for future research into IPD and SCM risks, the influence of organizational structures, and the role of emerging technologies and cultural factors in modular construction.

Keywords: Critical Success Factors; Implementation Framework; Integrated Project Delivery; Modular Construction; Supply Chain Management

INTRODUCTION

The application of prefabricated structures in the Philippines has traditionally been confined to temporary facilities, office buildings, and warehouses. Nonetheless, there is a growing acceptance of prefabrication within resorts and restaurants. Despite this trend, the utilization of prefabricated structures for residential purposes remains minimal. This limited adoption poses a significant concern given the pressing need for affordable housing in the country, with government projections indicating a requirement of 6.5 million units by 2022 (Pascual, 2021).

A fully modular structure epitomizes the highest level of technology in prefabricated construction, yet its implementation encounters substantial challenges. These challenges include high initial investment costs, the necessity for skilled labor, and a lack of standardized designs. Furthermore, the market demand for such structures is limited, compounded by logistical difficulties related to transportation costs and supply chain complexities (Kisi et al., 2019; Wang et al., 2019).

Effective Supply Chain Management (SCM) is crucial for overcoming these obstacles. In the context of modular construction, SCM involves managing the flow of materials and components from the manufacturing facility to the construction site. Establishing robust partnerships between suppliers and contractors is essential for optimizing efficiency and mitigating barriers to adoption (Ajayi et al., 2019). However, the construction supply chain is often fragmented and hindered by outdated management practices, resulting in inefficiencies and adversarial interactions among stakeholders (Aapaoja et al., 2013; Chen et al., 2020).

This paper concludes by emphasizing the necessity for the Philippine construction industry to fully embrace modular construction technologies. Addressing the challenges posed by a fragmented supply chain through Integrated Project Delivery (IPD) and SCM can significantly enhance the efficiency and sustainability of construction projects. Implementing these advanced construction methods is imperative for meeting the nation's housing needs and improving overall construction practices.

LITERATURE REVIEW

The construction industry is experiencing substantial transformations with the integration of modular construction, IPD, and advanced SCM practices. These innovations aim to enhance efficiency, reduce costs, and promote sustainability in construction projects.

Modular construction entails the off-site fabrication of building components, which are then transported and assembled on-site. This approach emphasizes prefabrication to minimize on-site activities, ensuring high quality and reducing waste. The benefits include shortened construction timelines, minimized waste, and enhanced sustainability due to factory-based manufacturing processes (Musa et al., 2016; Abdelmageed & Zayed, 2020). Internationally, countries like Singapore support modular construction through robust legal frameworks, while in the Philippines, the focus is on cost-efficiency and innovative use of local materials, such as Mt. Pinatubo ejecta for housing (Xu et al., 2020). However, modular construction faces challenges such as the need for precise manufacturing, skilled labor, and regulatory hurdles (Ferdous et al., 2019; Salama et al., 2020).

IPD represents a shift from traditional construction practices by prioritizing early collaboration, trust, and effective risk management. Core elements include ongoing stakeholder participation, aligned interests, collaborative project management, and multi-

party agreements (American Institute of Architects [AIA], 2014). Adoption of IPD varies by organizational size: small enterprises benefit from improved collaboration, medium-sized firms enhance stakeholder communication, and large enterprises manage complexities with established frameworks (Zaker & Coloma, 2018; Ebrahimi & Dowlatabadi, 2018; Ma et al., 2018). Executives, managers, and operational teams play crucial roles in IPD implementation, with their responsibilities varying by position and expertise (Nawi et al., 2017; Ochungo & Odinga, 2019; Safa et al., 2022).

SCM improves efficiency, reduces costs, and enhances stakeholder relationships by managing the flow of materials, information, and finances (Papadopoulos et al., 2016). Effective SCM in modular construction is essential for project success, requiring the overcoming of fragmented supply chains and logistical complexities (Wuni & Shen, 2023). Critical Success Factors (CSFs) for SCM include collaboration, communication, training, logistics management, performance monitoring, and demand forecasting (Thunberg et al., 2017; Wuni & Shen, 2023). The ability to implement these CSFs varies based on organizational size, technical expertise, and industry experience (Srimathi et al., 2017; Prasad & Vasugi, 2023; Chen et al., 2023).

Integration of SCM within IPD frameworks significantly enhances project efficiency and performance. Effective contractual agreements fostering collaboration, risk management, and technical advancements are crucial for successful SCM in IPD projects (Mesa et al., 2020; Ahmed et al., 2021; Andiana et al., 2024). The proposed implementation framework for IPD-based SCM in modular construction involves several key phases, beginning with a comprehensive pre-implementation assessment to evaluate the organization's readiness and align the framework with strategic goals (Ebrahimi & Dowlatabadi, 2018; Mesa et al., 2020). This is followed by customizing IPD and SCM strategies to meet specific organizational needs, including developing collaborative digital tools and key performance indicators (Ju et al., 2017; Elghaish et al., 2020). The implementation phase emphasizes targeted training and enhancing communication channels to promote shared decision-making processes (Shin et al., 2011; Irizarry et al., 2013). Continuous monitoring and evaluation are conducted to assess performance and adjust strategies, ensuring the framework remains effective (Mesa et al., 2020; Bhattacharya & Chatterjee, 2021).

The framework promotes best practices and scales successful implementations across the organization, fostering knowledge transfer and continuous improvement (Kilger, 2014; O'Mahony et al., 2021). Good governance principles, including transparency, accountability, inclusiveness, responsiveness, and ethical conduct, are integral throughout the framework, ensuring that processes are applied consistently and equitably (AIA, 2014; Papadopoulos et al., 2016; Darmansyah et al., 2024; Lestari et al., 2024). These principles enhance stakeholder engagement, trust, and responsiveness to feedback, ultimately leading to sustainable and improved project outcomes through increased efficiency and reduced costs.

RESEARCH METHOD

The methodology starts with a clear problem statement informed by existing literature. This problem statement guides the development of a structured questionnaire, which is meticulously validated through expert review and literature comparison. This validation process ensures the questionnaire's relevance and credibility. A pilot test involving 35 participants is conducted, utilizing Cronbach’s Alpha to assess the reliability of the questionnaire, ensuring the consistency of the data collected.

The data gathering phase involves a purposive sample of 186 respondents, selected for their specific involvement within the modular construction sector. This non-probability sampling method focuses on individuals who can provide in-depth knowledge and insights into the central phenomenon or key concepts under investigation. The demographic profile of the respondents includes a diverse range of construction companies of various sizes and with different levels of IPD implementation experience. This diversity allows for a comprehensive analysis of the data.

Subsequent data analysis is performed using rigorous statistical methods to ensure objective interpretation. Descriptive statistics, including mean scores and standard deviations, summarize the degree of IPD utilization and CSF compliance. Additionally, correlation analysis using Pearson correlation coefficients is employed to measure the relationship between IPD utilization and CSF compliance.

The results and discussions derived from this statistical treatment are aligned with existing literature, providing actionable insights. These insights inform the development of an implementation framework for IPD-based SCM in modular construction in the Philippines. The framework is designed to be adaptable to the specific needs and challenges faced by construction companies of different sizes and levels of IPD adoption .

RESULTS

Degree of IPD Utilization

Table 1 in the study showcases the utilization of IPD across various sizes of construction companies in the Philippines. The data, represented through mean scores and standard deviations, provides insights into how small, medium, and large enterprises engage with IPD principles differently.

Table 1. Degree of IPD Utilization of the Construction Companies in the Philippines

Degree of IPD Utilization among different Sizes of Construction Companies in the Philippines	Small		Medium		Large	
	Mean	SD	Mean	SD	Mean	SD
IPD 1. Continuously involve project stakeholders throughout the course of your projects	4.53	0.64	4.32	0.68	4.46	0.74
IPD 2. Align Business interests with your project stakeholders through Shared Risk & Reward that is dependent upon project outcomes	4.07	0.80	4.32	0.70	4.53	0.63
IPD 3. Observe Joint Project control and Decision-making by stakeholders on all stages of your projects	4.20	0.77	4.21	0.80	4.41	0.74
IPD 4. Utilize multi-party agreement or equal interlocking agreement with your project stakeholders	4.40	0.74	4.33	0.82	4.63	0.62
IPD 5. Encourage the project stakeholders to take accountability for their project rather than attempting to blame others through reduced liability	4.13	0.92	4.28	0.78	4.37	0.87
Overall Mean	4.27	0.77	4.29	0.76	4.48	0.72

Note: 1.0 to 1.80 = Very Low / 1.81 to 2.60 = Low / 2.61 to 3.40 = Moderate / 3.41 to 4.20 = High / 4.21 to 5.00 = Very High

Small-sized enterprises in the Philippines exhibit a commendable level of IPD utilization, with an impressive overall mean score of 4.27. These companies excel in maintaining continuous stakeholder involvement (mean score of 4.53), aligning business interests effectively, and engaging in joint project control and multi-party agreements. Their flexibility and adaptability enable effective implementation of collaborative IPD practices despite resource limitations. Literature supports these findings, indicating that IPD can lead to improved project outcomes such as shorter schedules and better quality, facilitated by technologies like Building Information Modeling (BIM) (Zaker & Coloma, 2018; Prasad & Vasugi, 2023).

Medium-sized enterprises also demonstrate robust IPD utilization, with an overall mean score of 4.29. They maintain high levels of stakeholder involvement and alignment of business interests (mean scores of 4.32 for both) and effectively engage in joint project control and multi-party agreements. This commitment to IPD principles reflects their balance of resources and flexibility, facilitating the adoption of IPD. Literature indicates that medium-sized companies are well-suited for effective IPD implementation due to their resource availability and ability to create a collaborative environment (Nawi et al., 2017; Ebrahimi & Dowlatabadi, 2018).

Large-sized enterprises display the highest levels of IPD utilization, with an overall mean score of 4.48. They exhibit very high levels of stakeholder involvement, business interest alignment, joint project control, and multi-party agreements (mean scores exceeding 4.4 for each metric). Their established structures and ample resources facilitate high IPD utilization, despite the complexities of their organizational structures. Literature corroborates these findings, noting that large enterprises benefit from resources and established structures that support IPD, although they face challenges in managing complexity and ensuring effective communication (Jayasena & Senevirathna, 2012; Ma et al., 2018).

Overall, construction companies in the Philippines demonstrate high to very high degrees of IPD utilization, with large-sized enterprises showing the highest overall mean score (4.48), followed by medium-sized (4.29) and small-sized enterprises (4.27). This indicates that IPD practices are well-implemented and prevalent across the industry, with the extent and focus of implementation varying based on company size, resources, organizational structures, and inherent flexibility. This trend underscores the widespread commitment to IPD principles within the Philippine construction industry, enhancing project efficiency and outcomes.

Compliance with CSFs in SCM

Table 2 elucidates the compliance of Philippine modular construction companies with CSFs for Supply Chain Management, segmented by company size. Through mean scores and standard deviations, the table reveals distinct compliance levels across small, medium, and large enterprises, summarizing their engagement with CSFs as follows:

Table 2. CSF Compliance Rate of the Construction Companies in the Philippines

CSF Compliance rate among different Sizes of Construction Companies in the Philippines	Small		Medium		Large	
	Mean	SD	Mean	SD	Mean	SD
CSF 1. Setup and prioritize common goals?	4.27	0.46	4.46	0.66	4.52	0.73
CSF 2. Create a project plan & schedule?	4.47	0.52	4.40	0.68	4.46	0.74
CSF 3. Monitor the real-time performance of the productivity level	3.67	0.90	4.06	0.90	4.22	0.85

CSF 4. Develop demand forecasts based on market surveys	3.53	1.41	4.11	1.01	4.16	1.05
CSF 5. Observe open, reliable, and accurate information sharing	4.07	0.70	4.27	0.72	4.40	0.77
CSF 6. Enforce system for planning, production, monitoring, & communication	4.27	0.70	4.41	0.72	4.48	0.73
CSF 7. Strategic alliancing and partnering agreements with suppliers	3.93	0.96	4.16	0.70	4.40	0.80
CSF 8. Supply chain education & training	3.73	0.96	4.04	0.76	4.42	0.77
CSF 9. Devise a Logistic Management plan	3.93	0.88	4.36	0.71	4.60	0.77
Overall Mean	3.99	0.83	4.25	0.76	4.41	0.80

Note: 1.0 to 1.80 = Very Low / 1.81 to 2.60 = Low / 2.61 to 3.40 = Moderate / 3.41 to 4.20 = High / 4.21 to 5.00 = Very High

Small-sized construction companies in the Philippines demonstrate a commendable level of compliance with CSF. They excel in creating project plans and schedules, achieving very high compliance with a Likert scale score of 4.47. These companies also effectively set common goals, with high compliance reflected by a score of 4.27. While they maintain high compliance in monitoring real-time productivity performance, there is room for improvement in this area, as indicated by a Likert scale score of 3.67. Similarly, they show potential for growth in demand forecasting, with moderate compliance indicated by a score of 3.53. Additionally, these enterprises exhibit high compliance in fostering open and reliable information sharing (Likert scale score of 4.07) and enforcing systematic project management and communication approaches (Likert scale score of 4.27). Strategic aspects like forming alliances with suppliers (high compliance with a Likert scale score of 3.93) and supply chain education and training (high compliance with a Likert scale score of 3.73) also indicate areas for improvement. Overall, with an average compliance rating of high (Likert scale score of 3.99), small-sized companies show a strong commitment to CSFs, aligning with their characteristic flexibility and adaptability (Juanzon & Muhi, 2017).

Medium-sized construction companies exhibit robust compliance with CSF metrics. They excel in creating project plans and schedules (Likert scale score of 4.40) and in setting common goals, achieving very high compliance with a Likert scale score of 4.46. These companies also maintain high compliance in monitoring real-time productivity performance (Likert scale score of 4.06) and demand forecasting (Likert scale score of 4.11). Additionally, they demonstrate high compliance in fostering open and reliable information sharing (Likert scale score of 4.27) and systematic project management and communication (Likert scale score of 4.41). Their commitment extends to forming alliances with suppliers (high compliance with a Likert scale score of 4.16) and supply chain education and training (high compliance with a Likert scale score of 4.04). Medium-sized enterprises also excel in logistic management plans, achieving very high compliance with a Likert scale score of 4.36. Overall, with an average compliance rating of high (Likert scale score of 4.25), medium-sized companies demonstrate a strong commitment to CSFs, leveraging their balance of resources and flexibility (Yong & Mustaffa, 2017).

Large-sized construction companies set a benchmark for CSF compliance. They excel in setting common goals, achieving very high compliance with a Likert scale score of 4.52, and creating precise project plans and schedules (Likert scale score of 4.46). They effectively monitor real-time productivity performance (high compliance with a Likert scale score of 4.22) and engage in demand forecasting based on market surveys (high compliance with a Likert scale score of 4.16). They foster open, reliable, and accurate

information sharing (high compliance with a Likert scale score of 4.40) and enforce systematic project management and communication approaches (very high compliance with a Likert scale score of 4.48). In strategic aspects like forming alliances with suppliers (high compliance with a Likert scale score of 4.40) and supply chain education and training (high compliance with a Likert scale score of 4.42), large-sized enterprises show their commitment to enhancing supply chain efficiency. They excel in logistic management plans, achieving very high compliance with a Likert scale score of 4.60. With an average compliance rating of very high (Likert scale score of 4.41), large-sized companies demonstrate exceptional commitment to CSFs, facilitated by their vast resources and established structures (Neyestani, 2016).

Overall, construction companies in the Philippines demonstrate a strong commitment to CSF compliance. Whether small, medium, or large, these enterprises emphasize setting common goals, effective project planning, and maintaining open communication within their teams. Large-sized enterprises particularly excel in CSF compliance, setting a benchmark for the industry. These findings highlight the industry's dedication to CSFs, contributing to effective project management and successful outcomes overall.

Variance in Assessments

Table 3 reveals the impact of demographic variables on the utilization of IPD within the modular construction industry, showcasing significant differences based on company size, position, and field of expertise, but not years of experience.

Table 3. Significant Difference in the Assessment of the Respondents in Terms of Degree of IPD Utilization

Variables		Mean	StDev	F-value	p-value	Decision	Remarks
Size of the Company	Small Enterprise	4.27	0.41	3.910	0.022	Reject Ho	Significant
	Medium Enterprise	4.29	0.47				
	Large Enterprise	4.48	0.45				
Position	Executive	4.29	0.46	10.570	< 0.001	Reject Ho	Significant
	Manager	4.24	0.46				
	Operations	4.57	0.42				
Field of Technical Expertise	Architecture	4.30	0.47	6.040	0.001	Reject Ho	Significant
	Construction	4.25	0.44				
	Engineering	4.54	0.43				
	Supply Chain	4.22	0.61				
Years of Work Experience	1 to 5 years	4.37	0.48	0.490	0.687	Do Not Reject Ho	Not Significant
	6 to 10 years	4.65	0.19				
	11 to 15 years	4.36	0.46				
	More than 15 years	4.40	*				

Note: 1.0 to 1.80 = Very Low / 1.81 to 2.60 = Low / 2.61 to 3.40 = Moderate / 3.41 to 4.20 = High / 4.21 to 5.00 = Very High, Reject Ho if $p < 0.05$

Small enterprises exhibited lower mean scores in IPD assessment compared to medium and large enterprises, indicating that company size significantly influences IPD perception. Smaller firms may be constrained by limited resources, affecting their capacity to implement IPD effectively (Prasad & Vasugi, 2023). In contrast, larger firms benefit from greater resource availability and more complex organizational structures, which can facilitate superior IPD implementation (Jayasena & Senevirathna, 2012; Darmansyah et al., 2024).

Operations personnel evaluated IPD more favorably than managers and executives. This variation is likely due to the direct involvement of operations personnel in project execution, making them more receptive to IPD's collaborative approach (Ochungo & Odinga, 2019). Conversely, managers and executives might focus more on the strategic implications of IPD adoption (Nawi et al., 2017).

Engineers perceived IPD utilization more positively compared to professionals in other fields. Given their roles in design and execution, engineers might be more attuned to the benefits of IPD (Granja et al., 2023). Conversely, architects and supply chain professionals may have different perspectives based on their specialized roles (Kahvandi et al., 2020).

Work experience did not significantly impact IPD assessment, indicating a uniform perception across different experience levels. This suggests that the benefits and challenges of IPD are similarly recognized by professionals, regardless of their years in the industry (Sherif et al., 2022; Buk'hail & Al-Sabah, 2022).

The assessment of IPD in the modular construction industry is influenced by a combination of factors, including company size, position within the company, and field of technical expertise. Each group brings unique perspectives to IPD, highlighting the need for targeted strategies to address these diverse viewpoints and enhance IPD acceptance and utilization across the industry's varied demographic landscape.

The statistical analysis of Table 4 focusing on CSF compliance across modular construction companies in the Philippines yields insightful distinctions influenced by company size, while position, technical expertise, and experience show varied impacts.

Table 4. Significant Difference in the Assessment of the Respondents in Terms of CSF Compliance Rate with CSF-SCM

Variables		Mean	StDev	F-value	p-value	Decision	Remarks
Size of the Company	Small Enterprise	3.99	0.41	6.42	0.002	Reject Ho	Significant
	Medium Enterprise	4.25	0.39				
	Large Enterprise	4.41	0.52				
Position	Executive	4.33	0.31	0.24	0.787	Do Not Reject Ho	Not Significant
	Manager	4.27	0.52				
	Operations	4.31	0.48				
Field of Technical Expertise	Architecture	4.37	0.29	1.04	0.375	Do Not Reject Ho	Not Significant
	Construction Management	4.23	0.52				
	Engineering	4.34	0.44				
	Supply Chain Management	4.34	0.34				
Years of Work Experience	1 to 5 years	4.24	0.54	1.16	0.328	Do Not Reject Ho	Not Significant
	6 to 10 years	4.39	0.19				
	11 to 15 years	4.36	0.36				
	More than 15 years	4.11	---				

Note: 1.0 to 1.80 = Very Low / 1.81 to 2.60 = Low / 2.61 to 3.40 = Moderate / 3.41 to 4.20 = High / 4.21 to 5.00 = Very High, Reject Ho if $p < 0.05$

Compliance rates with CSFs significantly differ among companies of various sizes. Small enterprises typically show lower compliance levels, likely due to resource constraints and adaptability challenges (Prasad & Vasugi, 2023). In contrast, medium-sized companies demonstrate the highest compliance, balancing their greater resources with strategic planning (Chen et al., 2023). Large enterprises also have notable compliance rates, although their organizational complexity might pose challenges (Srimathi et al., 2017).

Position within the company, whether executive, managerial, or operational, does not significantly impact CSF compliance. This uniformity suggests a shared understanding and commitment to CSFs across all levels within companies (Choi & O'Connor, 2014; Papadopoulos et al., 2016).

The field of technical expertise, including architecture, construction management, engineering, and supply chain management, shows no significant variations in CSF compliance. This indicates a broad acknowledgment of the importance of CSFs across various technical domains (Ochungo & Odinga, 2019; Ibrahim et al., 2021).

Survey findings indicate consistent compliance with CSFs across various levels of work experience in the modular construction industry. This suggests a general trend where adherence to established standards is uniformly recognized and applied, regardless of a professional's career stage (Aziz, 2013; Choi & O'Connor, 2014). However, the literature suggests variability in readiness to implement these CSFs, where newer professionals might be more open to innovative approaches, while experienced professionals might rely on established methods. This discrepancy likely arises from differentiating between compliance—following existing protocols—and readiness—the ability to adapt and innovate within the context of CSFs.

While company size and the degree of IPD utilization significantly influence CSF compliance in supply chain management, other factors like position within the company, field of technical expertise, and years of work experience do not exhibit a substantial impact. These findings underscore the importance of tailoring compliance strategies based on company size to enhance adherence to CSFs in supply chain management within the modular construction industry.

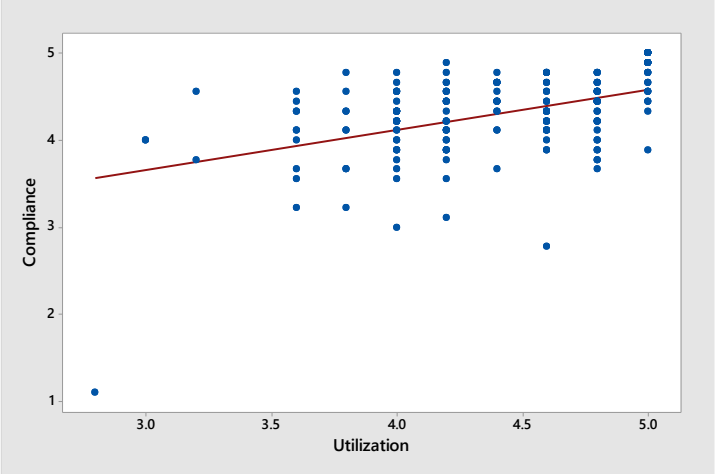
Correlation Between IPD Utilization and CSF Compliance

The correlation analysis conducted between the degree of IPD utilization and the CSFs of SCM in the Philippines reveals an interesting relationship.

Table 5. Correlation between the Degree of IPD Utilization and the Compliance Rate with CSF Among All Construction Companies in Philippines

Pearson R	0.466
p-value	< 0.001
Interpretation	Moderate
Decision	Reject Ho
Remarks	Significant

Figure 1. Correlation Graph Between the Degree of IPD Utilization and the Compliance Rate with CSF Among All Construction Companies in Philippines



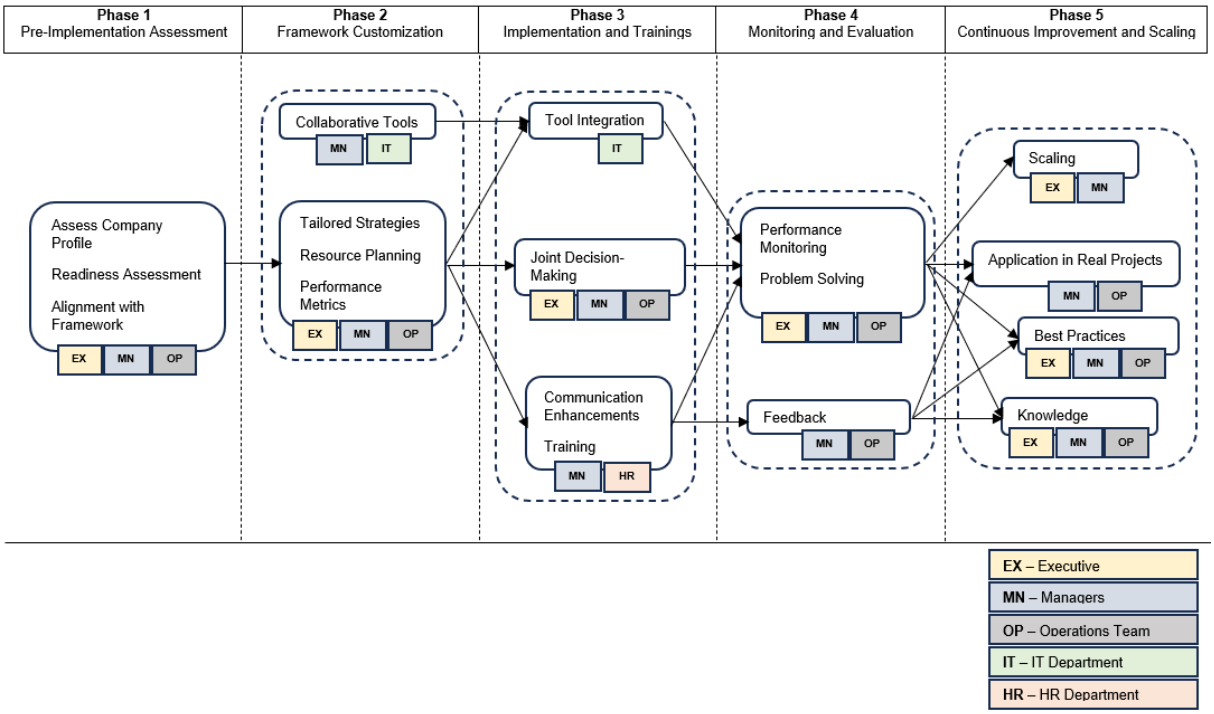
The calculated Pearson correlation coefficient of 0.466 reveals a moderate positive correlation between the utilization of IPD and compliance with CSFs in SCM within the construction industry. This correlation is statistically significant, as indicated by a p-value less than 0.001, suggesting that increased use of IPD is associated with higher compliance with CSFs.

The rejection of the null hypothesis further confirms that this relationship is genuine and not due to random chance. This finding aligns with research indicating that IPD's collaborative approach significantly enhances SCM effectiveness, leading to improved project outcomes (Mesa et al., 2020; Ahmed et al., 2021). Therefore, projects that extensively utilize IPD tend to exhibit better adherence to CSFs in SCM, highlighting the importance of integrating these approaches for successful project management in the construction industry.

Proposed Implementation Framework

In response to the insights garnered, the study proposes an implementation framework for IPD-based SCM of Modular Construction in the Philippines, taking into account the influence of company size, position within the company, technical field of expertise, and years of experience. This framework aims to guide companies through the process of integrating IPD principles into their SCM practices, emphasizing the need for continuous improvement and adaptation to local challenges and opportunities (Ahmed et al., 2021; Yan & Chen, 2023).

Figure 2. Proposed Implementation Framework for IPD-based Supply Chain Management of Modular Construction in Philippines



5 Phases of the Proposed Implementation Framework

The first phase, the pre-implementation assessment, aims to understand the current state of the organization and its readiness for IPD and SCM integration. This involves assessing the company's size, structure, and existing project management practices, evaluating stakeholder readiness for collaborative processes, and identifying available resources such as financial, technological, and human resources.

In the framework customization phase, the goal is to tailor IPD and SCM strategies to fit the unique needs of the organization. Customized solutions are developed to address potential conflicts and operational challenges specific to the company's size and project complexity. Digital tools and platforms, such as BIM and collaborative project management software, are selected and adapted to facilitate stakeholder collaboration and communication. Key Performance Indicators (KPIs) that align with the organization's goals are also established to measure project success.

The third phase, implementation and training, focuses on rolling out the IPD-based SCM system and equipping the team with the necessary skills and knowledge. Comprehensive training programs are developed and implemented for all stakeholders, covering IPD principles, SCM best practices, and the use of collaborative tools. The selected digital tools are integrated into daily workflows, and communication channels are enhanced to ensure transparent and effective information exchange among project participants.

During the monitoring and evaluation phase, the progress and effectiveness of the IPD and SCM integration are continuously assessed. Project performance is regularly tracked against the established KPIs using tools like BIM to identify bottlenecks. Feedback mechanisms, such as regular meetings, surveys, and suggestion systems, are set up to collect input from all stakeholders and identify areas for improvement.

Issues are addressed promptly with a flexible approach to adapt to new information and evolving project dynamics.

The final phase, continuous improvement and scaling, focuses on refining the framework and expanding its application to other projects. Best practices and lessons learned are documented and shared across the organization to promote continuous improvement. The refined framework is applied to new projects, ensuring that IPD and SCM principles are embedded in the company's standard operating procedures. Ongoing training and development opportunities are provided to keep the team updated on the latest practices.

Tailored Implementation Framework

The proposed implementation framework for integrating IPD principles into SCM in modular construction projects must be tailored to meet the specific needs of companies of varying sizes—small, medium, and large. Each size category faces unique challenges and possesses different capacities and resources that influence the adoption and execution of IPD and SCM strategies.

For small-sized enterprises (SMEs), the framework begins with a Pre-Implementation Assessment focused on evaluating their readiness for IPD and SCM integration. This involves identifying key stakeholders, financial resources, technological infrastructure, and workforce skills. Framework Customization for SMEs emphasizes cost-effective solutions and scalable technologies, selecting affordable digital tools to facilitate collaboration. Training programs are designed to enhance the skills of the existing workforce without incurring significant costs, and KPIs are focused on immediate, tangible improvements. During Implementation and Training, SMEs should adopt IPD and SCM practices in a phased manner to manage costs and disruptions, with hands-on, practical training and enhanced communication channels. Monitoring and Evaluation for SMEs involves straightforward techniques, such as weekly meetings and performance dashboards, to track progress and address issues promptly. Continuous Improvement and Scaling focus on incremental changes and practical solutions that can be scaled as the company grows, promoting a culture of continuous learning and improvement.

Medium-sized enterprises have more resources and a more complex organizational structure. Their pre-implementation assessment includes a detailed analysis of existing project management practices, technological capabilities, and stakeholder readiness. Framework customization for medium-sized enterprises involves selecting robust digital tools that integrate well with existing systems and support advanced features like BIM. Training programs should be comprehensive, covering both basic and advanced aspects of IPD and SCM, with KPIs addressing various aspects of project performance and supply chain efficiency. During implementation and training, a structured approach is adopted, rolling out IPD and SCM practices across different departments in stages. Training should be extensive and continuous, ensuring all employees understand the new processes and technologies. Regular meetings, integrated software platforms, and clear protocols enhance communication. Monitoring and evaluation for medium-sized enterprises should be data-driven, using advanced analytics to track performance against KPIs. Robust feedback mechanisms, such as bi-weekly review meetings and performance reports, help identify areas for improvement. Continuous improvement and scaling involve refining processes and expanding successful practices across the organization, with internal workshops and knowledge management systems promoting continuous improvement.

For large enterprises, which have extensive resources and highly complex organizational structures, the pre-implementation assessment is comprehensive, involving a detailed evaluation of existing IPD and SCM practices, technological infrastructure, and stakeholder readiness. Framework customization for large enterprises involves selecting advanced digital tools that handle the complexity and scale of their operations, supporting features like BIM, project management software, and enterprise resource planning (ERP) systems. Training programs are tailored to different levels of the organization, ensuring everyone understands their role in the IPD and SCM processes, with comprehensive KPIs covering all aspects of project performance and supply chain management. During implementation and training, a phased approach is adopted, starting with pilot projects before scaling up. Continuous and segmented training addresses the specific needs of different departments and roles. Integrated platforms, regular cross-departmental meetings, and clear protocols enhance communication. Monitoring and evaluation for large enterprises leverage advanced analytics and real-time data monitoring, with comprehensive performance management systems tracking progress and identifying areas for improvement. Detailed feedback mechanisms, such as quarterly reviews and in-depth performance reports, support continuous improvement. Continuous improvement and scaling focus on embedding IPD and SCM practices into the organizational culture, promoting regular training, workshops, and knowledge sharing. Scaling successful practices across projects and departments helps standardize processes and enhance efficiency, with continuous investment in advanced technologies and training supporting long-term growth.

DISCUSSION

The findings reveal critical insights into the utilization of IPD and adherence to CSFs in SCM across different company sizes within the Philippine construction industry. These insights lay a robust foundation for developing an effective implementation framework tailored to the varying needs of organizations.

The research assessed the degree of IPD utilization across small, medium, and large enterprises, finding that larger enterprises exhibited a higher degree of IPD utilization compared to smaller companies. Larger companies benefit from established processes and resources that facilitate IPD, despite facing significant challenges due to their complex organizational structures. In contrast, smaller companies showed moderate IPD utilization, benefiting from their flexibility and adaptability, but were constrained by limited resources.

Compliance with CSFs was also evaluated, revealing notable differences across company sizes. Smaller companies demonstrated agility and adaptability despite their resource limitations, while medium-sized companies managed broader aspects of SCM effectively. Large enterprises exhibited robust adherence to CSFs, supported by their extensive resources. These findings highlight the varying capacity and focus areas of companies based on their size and available resources.

A moderate positive correlation was found between the degree of IPD utilization and the compliance rate with CSFs. This suggests that companies with higher IPD adoption tend to comply more with SCM best practices. The collaborative nature of IPD contributes to enhanced SCM effectiveness, leading to better project outcomes. This finding underscores the importance of integrating IPD and SCM strategies to achieve optimal performance in modular construction projects.

Based on the findings, it is evident that the adoption of IPD and adherence to CSFs in SCM are pivotal for the success of modular construction projects in the Philippines. The degree of IPD utilization and CSF compliance varies significantly across different company sizes, with larger enterprises showing higher levels of both due to their established processes and extensive resources. Smaller companies, while agile and adaptable, face challenges related to limited resources but still benefit from the collaborative advantages of IPD. The research highlights a moderate positive correlation between IPD utilization and CSF compliance, indicating that companies adopting IPD more extensively tend to achieve better SCM practices. This relationship underscores the synergistic benefits of integrating IPD with SCM to enhance project outcomes.

CONCLUSION

To address these findings, several recommendations are proposed. First, developing and implementing a tailored framework for IPD-based SCM that considers the unique needs and capacities of small, medium, and large enterprises is crucial. This framework should be flexible enough to adapt to the specific challenges and resource constraints of each company size. Emphasizing continuous improvement and providing ongoing training programs to enhance the skills of the workforce in IPD and SCM practices is also recommended. Regular training and development opportunities will ensure that all employees are well-versed in the latest methodologies and technologies.

Furthermore, efficient resource allocation to support the adoption of IPD and SCM practices, particularly for smaller companies, is essential. Government and industry stakeholders should consider providing financial and technical support to help smaller enterprises overcome resource limitations. Fostering a culture of collaboration and open communication among all stakeholders involved in modular construction projects is also vital. Utilizing digital tools such as Building Information Modeling (BIM) can facilitate real-time collaboration and information sharing, enhancing project efficiency and effectiveness. Lastly, implementing robust monitoring and evaluation systems to track progress and performance against established KPIs will help identify areas for improvement and ensure that IPD and SCM practices are being effectively integrated and optimized.

By implementing these recommendations, construction companies in the Philippines can improve their IPD and SCM practices, leading to enhanced project efficiency, quality, and sustainability in the modular construction sector. These steps will help ensure that the benefits of IPD and SCM are fully realized, contributing to the overall advancement of the construction industry in the region.

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DECLARATION OF CONFLICTING INTERESTS

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