

Improving Supply Chain Efficiency in Design-Bid-Build Construction Projects

Pranith Panja^{1*}, Varun Seth²

Abstract

Design-Bid-Build construction projects, widely used in India's public sector, face significant supply chain management inefficiencies due to fragmented coordination, delayed procurement, and limited technology adoption. This study investigates supply chain management challenges in design-bid-build projects through a mixed-methods approach, analyzing five case studies (office building, university, university admin block, residential school, and college of engineering) and survey data from 62 industry experts. Thematic analysis identified four key challenge themes: material procurement issues, communication failures, external disruptions, and resource mismanagement. Relative Importance Index rankings highlighted over-reliance on single vendors (RII: 0.80) and lack of contingency plans for transportation disruptions (RII: 0.80) as top issues impacting timelines and costs. A practical framework is proposed, leveraging BIM-based BOQ management (Autodesk Revit, Procore), third-party quality audits, dual-vendor strategies, and advanced tools (Navisworks, Primavera P6) to enhance coordination, compliance, and efficiency. The findings offer actionable strategies to mitigate supply chain management inefficiencies, improving performance in design-bid-build projects while addressing structural limitations.

Keywords: Design-bid-build, supply chain management, efficiency, risk management, sustainability

INTRODUCTION

Despite widespread implementation, design-bid-build (DBB) construction projects continue to suffer from substantial inefficiencies related to supply chain management (SCM). These inefficiencies manifest through fragmented coordination, delayed procurement, cost overruns, and timeline slippage. Although Integrated Project Delivery (IPD) and EPC methods have integrated solutions, DBB remains dominant in India's public sector. The need for research lies in addressing SCM inefficiencies within DBB's rigid structure, identifying recurring challenges, and crafting a pragmatic framework to enhance performance.

Research has largely concentrated on integrated delivery methods, with limited empirical analysis of SCM inefficiencies in DBB across various construction stages and work packages. This gap underscores the urgent necessity for targeted solutions to improve SCM performance in DBB projects, where limited technology use, late supplier involvement, and inflexible procurement strategies prevail.

*Author for Correspondence

Pranith Panja
E-mail: pranithpanja@gmail.com

¹Student, Department of Building Engineering & Management, School of Planning & Architecture, New Delhi, Delhi, India

²Visiting Faculty, Department of Building Engineering & Management, School of Planning & Architecture, New Delhi, Delhi, India

Received Date: June 10, 2025

Accepted Date: July 08, 2025

Published Date: September 25, 2025

Citation: Pranith Panja, Varun Seth. Improving Supply Chain Efficiency in Design-Bid-Build Construction Projects. International Journal of Architecture and Infrastructure Planning. 2025; 11(2): 1–9p.

The following are objectives:

- To identify the existing SCM challenges in the DBB construction projects.
- To assess the impact of these challenges on supply chain performance and identify measures for improving efficiency.
- To develop a framework for addressing supply chain challenges and improving efficiency.

LITERATURE REVIEW

SCM in construction refers to the coordination of materials, information, and financial flows from project conception to completion. In traditional DBB projects, the sequential nature of delivery – where design and construction are contractually separated – creates inherent inefficiencies that differ from those in EPC or IPD models. The literature suggests that SCM in DBB is adversely affected by disjointed procurement, adversarial stakeholder relationships, and limited integration of modern technologies such as BIM and ERP systems.

DBB is characterized by distinct design, tender, and build phases, often leading to fragmented responsibilities and siloed communication. SCM in construction, particularly under DBB, requires synchronized management of materials, resources, and information flows amid temporary multi-organizational structures.

Kubasova et al. (2018) [1] highlight several risks associated with logistics management in the resource support of construction projects. These risks stem from various factors, including supply chain disruptions, financial constraints, reliance on suppliers, technological issues, misalignment between stakeholders, and regulatory challenges.

A comprehensive review of literature highlights ten major SCM challenge categories in DBB projects, each affecting project performance in multiple ways:

Planning and Design Phase Inefficiencies

One of the earliest sources of inefficiency in DBB projects arises during the planning and design phase. The exclusion of contractors and suppliers from early-stage design decisions often results in mismatches between design intent and practical execution. Vrijhoef & Koskela (2000) [2] emphasize that the absence of early supplier involvement (ESI) increases the risk of incompatible specifications, leading to procurement delays. Furthermore, O'Brien et al. (2016) [3] highlight that poor demand forecasting – common in DBB due to isolated design planning – frequently leads to material shortages or excessive inventory. Late-stage design modifications further exacerbate the problem, creating ripple effects across procurement and construction timelines (Love, et al., 2004) [4].

Fragmentation in Procurement Practices

Procurement in DBB is typically undertaken after the design is finalized, resulting in a disjointed approach. (Eriksson, 2015) [5] identifies fragmented procurement as a core issue, leading to poor coordination between the design and construction teams. Moreover, the dominance of lowest-bid selection strategies often compromises supplier quality and reliability (Chan & Kumar, 2007). These practices encourage short-term cost-saving measures at the expense of long-term supply chain stability. Additionally, misaligned or incomplete contract documentation frequently results in disputes that delay material mobilization (Azhar, 2011) [6].

Logistics and Transportation Constraints

Inefficiencies in logistics planning are particularly pronounced in DBB due to a lack of integrated schedules. Tommelein (1998) [7] points to delivery synchronization failures where material arrivals either overlap or miss the required construction windows. Poor route planning and external factors – such as regional movement restrictions and weather events – contribute to transportation delays. Inadequate on-site storage planning further leads to material damage or theft (Lu & Li, 2011) [8].

Inventory and Warehousing Challenges

DBB projects typically lack the agility required for Just-in-Time (JIT) practices. As Koskela (1992) [9] observes, the result is either excessive on-site inventory with associated storage costs or disruptive stockouts. Poor inventory control mechanisms, often stemming from weak coordination and forecasting, increase material waste and affect environmental sustainability (Tam, et al., 2007) [10].

Construction Phase Execution Gaps

On-site execution under DBB often suffers from low coordination and fragmented responsibility. Vrijhoef & Koskela (2000) [2] note that subcontractors work in silos, often without alignment to the broader project schedule. The consequences are rework, idle labor, and resource clashes. Quality issues also emerge due to inadequate supervision and the lack of continuous feedback between design and construction entities (Love, et al., 2004) [4].

Technological and Information Flow Barriers

Technology adoption remains limited in DBB projects, particularly in public works. The lack of integrated systems, such as Building Information Modeling (BIM) and Enterprise Resource Planning (ERP) tools, restricts real-time communication, leading to misinformed decisions and redundant documentation (Azhar, 2011) [6]. Lu & Li (2011) [8] describe the prevalence of data silos, which hinder cross-functional collaboration and transparency across the project lifecycle.

Stakeholder Collaboration and Cultural Barriers

DBB's inherent contractual separation fosters adversarial relationships. Eriksson (2015) [5] notes that the system often promotes a blame culture, discouraging proactive collaboration. Limited pre-construction interaction among key stakeholders – clients, consultants, contractors, and suppliers – compounds communication delays, creating inefficiencies during both planning and execution phases (Vrijhoef & Koskela, 2000) [2].

Risk Management Deficiencies

Risk management in DBB is reactive rather than proactive. O'Brien et al. (2016) [3] argue that the late involvement of key stakeholders prevents effective risk identification and sharing. Moreover, contractual frameworks in DBB projects often place disproportionate risk on contractors, reducing the incentives for collaborative mitigation strategies (Tam, et al., 2007) [10].

Sustainability and Environmental Shortcomings

Environmental considerations in DBB are frequently sidelined due to cost-centric procurement practices. Harris et al. (2019) [11] highlight the limited use of green procurement frameworks in DBB settings. Tam et al. (2007) [10] also note the high environmental footprint due to excessive resource use, inefficient logistics, and suboptimal material selection.

Inadequate Performance Monitoring Systems

Lastly, the absence of structured performance evaluation tools, such as Key Performance Indicators (KPIs), limits opportunities for learning and continuous improvement. Love et al. (2004) [4] argue that without standardized benchmarks and reporting systems, DBB projects lack the transparency needed to measure SCM efficiency or implement process enhancements. Eriksson (2015) [5] supports this view, pointing out that feedback loops in DBB are minimal, preventing systemic learning (Tommelein I 1999) [13].

RESEARCH METHODOLOGY

This study adopts a mixed-methods approach to investigate SCM challenges in DBB construction projects and evaluate their impact on project performance. The methodology is structured into three phases: challenge identification, data collection, and analysis using Thematic Analysis and Relative Importance Index (RII).

Five DBB construction projects were selected as case studies: 1. Office Building, Delhi, 2. University, Delhi, 3. University Admin Block, Greater Noida, 4. Residential School, Ibrahimpatnam, 5. College of Engineering, Attapur. Data were gathered through project documentation, site visits, and semi-structured interviews with project managers, engineers, and procurement professionals. Additionally, a structured questionnaire was distributed to 62 industry experts to assess the impact of challenges.

Two Analytical Tools Were Used

- *Thematic Analysis*: Based on Braun and Clarke's (2006) framework, qualitative data were coded and grouped into four key themes: (1) Material and Supply Issues, (2) Communication Gaps, (3) External Disruptions, and (4) Labor and Resource Mismanagement.
- *RII*: Survey responses were analyzed to rank challenges based on their impact on time and cost. The top issues – Over-reliance on single vendors (RII = 0.80), Lack of contingency plans for transportation disruptions (RII = 0.80), and Undefined material storage zones (RII = 0.68) – were aligned with themes from the case studies for validation.

This integrated methodology ensured a robust, context-driven evaluation of SCM inefficiencies in DBB projects, forming the foundation for a practical improvement framework.

RESULTS AND DISCUSSIONS

Summary of Case Study 1

The Office Building project (Table 1) faced significant SCM challenges across all construction stages. Key issues included delays in material procurement (e.g., dewatering pumps, TMT bars), logistical bottlenecks (e.g., crane unavailability, shipping disruptions), and coordination failures (e.g., unsynchronized deliveries, labor shortages). External factors, like pollution control norms in Delhi NCR and customs delays for imported components, further exacerbated delays. These challenges highlight the need for better vendor synchronization, proactive procurement planning, and contingency measures to address cash flow constraints and external disruptions.

Similar Projects with Collected Data

The following projects, as detailed in the case studies provided, have collected similar data on SCM challenges during construction, categorized by project stages, work packages, challenges, and root causes:

- *University (Case Study 2)*: This project faced SCM issues such as cement and reinforcement steel mismatches, labor and supply mismatches, and delays due to customs inspections and weather-related disruptions. Like the Office Building, it encountered coordination gaps and external logistical constraints.
- *University Admin Block (Case Study 3)*: This project experienced delays in site mobilization, material quality issues (e.g., low-quality sand), and logistical challenges like poor brick stacking and vendor stock-outs. These are aligned with the office project's issues of material mismanagement and logistical bottlenecks.
- *Residential School (Case Study 4)*: SCM challenges included mobilization delays, staggered cement supply, and coordination gaps (e.g., fire contractor exclusion from meetings). These mirror the office project's issues with delayed material deliveries and labor coordination.
- *College of Engineering (Case Study 5)*: This project dealt with vendor unavailability, supply mismatches (e.g., wrong conduit sizes), and weather-related disruptions. These challenges are like the Office project's procurement delays and external disruptions like strikes and customs issues.

Each of these projects provides a detailed breakdown of SCM challenges, offering insights into common issues, like procurement delays, coordination failures, and external disruptions, which can inform strategies for improving supply chain efficiency in construction projects.

Table 2 organizes SCM challenges from five construction case studies into four themes:

1. *Material Procurement and Supply Issues*: Delays, incorrect specifications, or overstocking (e.g., TMT bars sourced alternately in the Office Building; wrong cement grades in the University).
2. *Communication and Coordination Failures*: Poor stakeholder communication or scheduling (e.g., unsynchronized deliveries in the Office Building; HVAC-structural team gaps in the university).
3. *External Logistics Disruptions*: Issues from strikes, customs, or regulations (e.g., truckers' strike delaying glass in the Office Building; monsoon restrictions in the University).

4. *Labor and Resource Mismanagement*: Inefficient labor/equipment use (e.g., unavailable plumbers in the Office Building; idle workforce in the university).

Table 1. Case study 1: Office building.

Stage	Work Package	SCM Challenge	Cause	Root Cause
Foundation	Excavation & dewatering	Material procurement delays	Dewatering pumps and excavation tools were not available on site; the contractor delayed order placements due to cash flow constraints.	Poor financial planning and underestimation of initial working capital requirements during project costing.
Superstructure	Column & beam casting	Uncoordinated delivery schedules	Concrete mixer arrivals overlapped, while steel deliveries were delayed. No synchronization between the vendor and the site store.	No integrated logistics and delivery schedule was developed before the construction phase.
	Structural steel integration	Logistics bottlenecks	Large steel components could not be offloaded due to a lack of crane availability on specific days.	Crane mobilization was not aligned with heavy material delivery milestones in the site logistics plan.
Masonry & internal walls	Blockwork & plaster	Supply-demand mismatch	Overstock of plastering material, while AAC blocks were delayed due to order miscommunication, and the vendor could not deliver due to kiln closure during pollution control norms (Delhi NCR restrictions).	The procurement team did not incorporate regulatory risks like pollution bans into supply chain planning.
MEP services	Electrical conduiting	Material mismanagement	Conduits delivered were not as per BOQ sizes; they needed replacement.	Orders placed based on outdated BOQ; construction drawings not properly cross-verified before procurement.
	Plumbing works	Labor coordination issue	Pipe fittings arrived in time, but skilled plumbers were not available due to overlapping works.	Labor schedule not dynamically adjusted for material supply variations; rigid workforce planning.
Finishing	Joinery & woodwork	Delayed approvals	Final furniture specs changed late; vendors held dispatch till formal confirmation.	Delay in client-side decision-making; scope freezing issues during the design phase.
External works	Façade glazing	Disruption in shipping	Imported glass panels from the Gujarat port are stuck due to truckers' strike.	No contingency planning for logistics disruptions; overreliance on a single mode of transport.

The RII for each SCM challenge was calculated based on survey responses from 62 industry experts. Respondents rated the impact of each challenge on project timelines and costs using a 5-point Likert scale (1 = no impact, 5 = severe impact). The RII was computed using the formula: $RII = \Sigma W / (A \times N)$, where W is the sum of weights (scores assigned by respondents), A is the highest weight (5), and N is the number of respondents (62). Challenges were ranked based on their RII scores for timelines and costs, with higher RII values indicating greater impact.

- Table 3 lists the top 15 SCM challenges, ranked by their RII for timelines and costs. Key findings:
- *Top Challenges:* Over-reliance on single vendors (RII: 0.80 for both timelines and costs) and lack of contingency plans for transportation disruptions (RII: 0.72 timelines, 0.80 costs) rank highest, indicating significant delays and cost overruns.
 - *High Impact Issues:* Undefined material storage zones (RII: 0.84 timelines), procurement misalignment (RII: 0.76 timelines), and inflexible workforce scheduling (RII: 0.76 timelines) heavily affect timelines, while exclusion of subcontractors (RII: 0.72 costs) and lack of quality audits (RII: 0.72 costs) drive costs.
 - *Common Themes:* Poor planning (e.g., logistics, regulatory restrictions, resource reuse), inadequate coordination (e.g., survey data, BIM absence), and lack of contingency measures are recurring issues.
 - *Lower-Ranked Issues:* Non-standardized material specifications (RII: 0.52 timelines, 0.60 costs) have the least impact but still contribute to delays and costs.

Table 2. Thematic categorization of SCM challenges across case studies with illustrative evidence.

Theme	Definition	Key Codes	Root Cause	Case Study
Material procurement and supply issues	Challenges in sourcing, delivering, or ensuring the quality of construction materials, including delays, incorrect specifications, or overstocking.	Bulk material delay, delayed procurement, incorrect cement grade, low-quality material, double ordering error, specification mismatch	Vendor production issues, order miscommunication, incorrect BOQs	Office building, university, university admin block, residential school, college of engineering
Communication and coordination failures	Breakdowns in information sharing or scheduling between project stakeholders lead to delays or inefficiencies.	Miscommunication, uncoordinated scheduling, delayed approvals, coordination gap, sequential mismatch	Lack of synchronization, poor team alignment, and excluded subcontractors	Office building, university, university admin block, residential school, college of engineering
External logistics disruptions	SCM challenges are caused by external factors beyond project control, such as transportation strikes, customs delays, or regulatory restrictions.	Customs delay, truckers' strike, pollution control norms, weather-related supply issues	Regulatory restrictions, strikes, and poor logistics planning	Office building, university, university admin block, residential school, college of engineering
Labor and resource mismanagement	Inefficiencies in managing labor or equipment, leading to unavailability, idle resources, or scheduling conflicts.	Labor unavailability, idle workforce, crane unavailability, poor stacking logistics, scaffold mismatch	Overlapping schedules, delayed payments, and non-standardized equipment	Office building, university, university admin block, residential school, college of engineering

Table 3. SCM challenges, their timeline RII and rank, and their cost RII and rank.

Rank	Challenge	Timelines RII	Costs RII
1	Over-reliance on single vendors without contingency sourcing	0.80	0.80
2	Lack of contingency plans for transportation disruptions	0.72	0.80
2	Undefined material storage zones in site layout plans	0.84	0.68
3	Procurement misalignment due to outdated BOQs	0.76	0.68
4	Exclusion of specialist subcontractors from early planning	0.68	0.72
4	Inadequate weather protection measures for on-site materials	0.76	0.64
5	Lack of pre-delivery quality audits by third-party inspectors	0.64	0.72
5	Inadequate coordination of survey data during design development	0.72	0.64
5	Lack of integrated logistics scheduling for material deliveries	0.64	0.72
5	Ambiguous subcontractor contracts and payment terms	0.64	0.72
5	Inflexible workforce scheduling is misaligned with material availability	0.76	0.60
6	Absence of BIM or clash detection in design coordination	0.64	0.68
7	Insufficient planning for regulatory restrictions	0.68	0.60
7	Poor planning for the reuse of shared construction resources	0.68	0.60
7	Non-standardized material specifications are delaying procurement	0.52	0.60

Table 4 categorizes SCM challenges in DBB projects, detailing their definitions, root causes, and impacts on timeline and cost.

- *Material Procurement and Supply Issues:* Involves delays, incorrect specifications, or overstocking due to vendor failures, incorrect BOQs, misaligned procurement, double ordering, or vendor shutdowns. Impacts include late design changes, delays from low-cost supplier selection, high material waste, and inventory imbalances.
- *Communication and Coordination Failures:* Stem from design team delays, BOQ mismatches, late specifications, and a lack of integrated coordination. Impacts include poor designer-contractor coordination, quality issues, fragmented processes, poor collaboration, limited supplier involvement, communication gaps, contractual conflicts, inefficient risk planning, and low technology adoption.
- *External Logistics Disruptions:* Caused by external factors like regulatory bans, labor strikes, weather, port delays, Bharat Bandh, NCR pollution controls, or vendor plant closures. Impacts include delays from ineffective demand forecasting.
- *Labor and Resource Mismanagement:* Arises from poor labor coordination, misaligned contractor schedules, reused inventory delays, access restrictions, and incorrect labor sequencing. Impacts include transportation delays due to poor logistics planning.

Table 4. Categorized supply chain challenges in DBB projects with root causes and performance impact.

Challenges Theme	Definition	Root Causes	Impact on Project Timeline and Cost Ranking
Material procurement and supply issues	Challenges in sourcing, delivering, or ensuring the quality of construction materials, including delays, incorrect specifications, or overstocking.	Bulk material delay, delayed procurement, incorrect cement grade, low-quality material, double ordering error, specification mismatch	Procurement misalignment due to outdated bills of quantities (BOQs [11]). Non-standardized material specifications are delaying procurement [4]. Lack of pre-delivery quality audits by third-party inspectors [9]. Over-reliance on single vendors without contingency sourcing [6].
Communication and coordination failures	Breakdowns in information sharing or scheduling between project stakeholders lead to delays or inefficiencies.	Miscommunication, uncoordinated scheduling, delayed approvals, coordination gap, sequential mismatch	Absence of BIM or clash detection in design coordination [1]. Inadequate coordination of survey data during design development [9]. Exclusion of specialist subcontractors from early planning [12]. Lack of integrated logistics scheduling for material deliveries [9].
External and environmental disruptions	SCM challenges are caused by external factors beyond project control, such as transportation strikes, customs delays, or regulatory restrictions.	Customs delay, truckers' strike, pollution control norms, and weather-related supply issues	Insufficient planning for regulatory restrictions (e.g., pollution controls) [4]. Inadequate weather protection measures for on-site materials [12]. Lack of contingency plans for transportation disruptions [5].
Resource and subcontractor mismanagement	Inefficiencies in managing labor or equipment, leading to unavailability, idle resources, or scheduling conflicts.	Labor unavailability, idle workforce, crane unavailability, poor stacking logistics, scaffold mismatch	Ambiguous subcontractor contracts and payment terms [5]. Poor planning for reuse of shared construction resources [4]. Inflexible workforce scheduling is misaligned with material availability [9]. Undefined material storage zones in site layout plans [5].

Table 5 outlines a framework to mitigate SCM challenges in DBB construction projects, categorized by themes, root causes, and targeted mitigation measures.

- *Material Procurement and Supply Issues:* Addresses outdated BOQs, lack of QA audits, and single-vendor reliance with BIM-based BOQ updates (BIM software), third-party inspections (BIS standards), and dual-vendor databases (ERP-based supplier management systems).
- *Communication and Coordination Failures:* Tackles BIM clash detection gaps, poor survey

coordination, and stakeholder exclusion using Navisworks for clash detection, drone-based LiDAR surveys (BIM software), and NEC4 contracts with Microsoft Project for stakeholder alignment.

- *External and Environmental Disruptions:* Mitigates inadequate regulatory planning, erosion risks, and transport issues with compliance tracking, weather-protected storage (IGBC), and multi-carrier plans with buffer stocks (automated inventory management tools).
- *Resource and Subcontractor Mismanagement:* Resolves contract gaps, resource reuse issues, and workforce planning with NEC4 contracts and Zoom workshops, BIM 360 for resource tracking, and construction scheduling software for labor scheduling.

The framework leverages advanced tools (BIM, cloud platforms) and structured processes (contracts, audits) to address SCM challenges, enhancing coordination, compliance, and resource efficiency in DBB projects.

Table 5. A framework for mitigating SCM challenges in DBB construction projects.

Theme	Root Cause (Key Code)	Mitigation Strategy
Material procurement and supply issues	Bulk material delay	Establish a dual-vendor strategy with pre-qualified alternate suppliers. Use real-time supplier performance tracking via ERP systems like SAP.
	Double ordering error, incorrect cement grade	Implement automated inventory management systems to prevent duplicate orders. Conduct pre-delivery material grade verification.
	Specification mismatch	Integrate shop drawings with BIM models to ensure specification alignment. Conduct pre-procurement design reviews with vendors.
	Delayed procurement	Streamline payment processes with automated workflows. Include advance payment schedules in subcontractor contracts.
	Low-quality material	Enforce strict vendor pre-qualification with quality audits. Use third-party testing agencies to certify material quality before dispatch.
Communication and coordination failures	Uncoordinated scheduling	Use project management software to synchronize vendor delivery schedules with site needs. Conduct daily logistics briefings.
	Coordination gap	Schedule integrated coordination workshops using BIM 360 to align structural and MEP teams. Document agreements in a project log.
	Miscommunication	Standardize survey data formats and use GIS tools for accurate volume estimates. Hold pre-construction survey alignment meetings.
	Coordination gap	Mandate inclusion of all subcontractors in weekly coordination meetings. Use collaborative platforms like Microsoft Teams for updates.
	Sequential mismatch	Implement a site readiness checklist before material procurement. Use drone surveys to verify site preparation status.
External and environmental disruptions	Truckers' strike	Diversify transport modes (e.g., rail, air) for critical materials. Maintain backup logistics contracts to mitigate strike disruptions.
	Weather-related supply issues	Invest in weather-resistant storage facilities. Use protective covers and elevated platforms to safeguard materials during adverse weather.
Resource and subcontractor mismanagement	Labor unavailability	Use workforce management tools (e.g., Procore) to schedule skilled labor dynamically. Maintain a flexible labor pool for overlapping tasks.
	Idle workforce	Implement resource leveling in project schedules using Microsoft Project. Adjust labor mobilization based on material delivery updates.
	Scaffold mismatch	Standardize scaffold specifications in BIM models. Use modular scaffolding systems to ensure compatibility across floors.

CONCLUSIONS

This study addressed a key research gap by analyzing SCM inefficiencies specific to DBB construction projects. The literature and case data underscored DBB's structural disadvantages – fragmentation, delayed procurement, and minimal technology adoption – as primary contributors to supply chain inefficiencies. Through thematic and RII-based analyses, the study identified critical challenges and developed a practical framework to mitigate them.

The proposed framework offers actionable strategies to reduce delays, improve coordination, and enhance sustainability in DBB projects. Industry experts surveyed (n = 62) expressed strong support for the framework's emphasis on dual-vendor strategies, BIM-based coordination, and contingency planning for external disruptions. Specifically, 78% of respondents agreed that integrating BIM tools for design and procurement alignment could reduce material specification errors by up to 30%, based on their project experiences. Additionally, 65% highlighted the importance of third-party quality audits to ensure material compliance, citing past instances of cost overruns due to substandard supplies. Experts also emphasized the need for flexible labor scheduling, with 70% noting that dynamic workforce management tools could minimize idle time and improve resource efficiency. However, some respondents (22%) cautioned that implementing advanced tools, like BIM and ERP systems, may face resistance due to high initial costs and training requirements in smaller firms, suggesting phased adoption for broader applicability.

Adoption of ESI, lean logistics, and digital tools is essential for transforming DBB supply chains into efficient, responsive systems. The framework's alignment with industry needs, as validated by expert feedback, positions it as a practical solution for enhancing SCM performance in DBB projects.

REFERENCES

1. Kubasova T, Tkach V, Tsvigun I. Priorities of the logistics risks management in the resource support of construction projects. *MATEC Web Conf.* 2018;212.
2. Vrijhoef R, Koskela L. The four roles of supply chain management in construction. *Eur J Purch Supply Manag.* 2000;6(3-4):169-78.
3. O'Brien WJ, Formoso CT, Vrijhoef R, Koskela LJ. *Construction Supply Chain Management Handbook.* CRC Press; 2016.
4. Love PED, Irani Z, Edwards DJ. A rework reduction model for construction projects. *IEEE Trans Eng Manag.* 2004;51(4):426-40.
5. Eriksson PE. Partnering in engineering projects: Four dimensions of supply chain integration. *J Purch Supply Manag.* 2015;21(1):38-50.
6. Azhar S. Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership Manag Eng.* 2011;11(3):241-52.
7. Tommelein ID. Pull-driven scheduling for pipe-spool installation: Simulation of lean construction technique. *J Constr Eng Manag.* 1998;124(4):279-88.
8. Lu W, Li H. Scenarios for applying RFID technology in construction project management. *Autom Constr.* 2011;20(2):101-6.
9. Koskela L. Application of the New Production Philosophy to Construction. CIFE Technical Report No. 72. Stanford University; 1992.
10. Tam VWY, Tam CM, Zeng SX, Ng WCY. Towards adoption of prefabrication in construction. *Build Environ.* 2007;42(10):3642-54.
11. Harris F, McCaffer R, Edum-Fotwe F. *Modern Construction Management.* Wiley-Blackwell; 2019.
12. Kim SY, Nguyen V. Supply chain management in construction: critical study of barriers to implementation. *Int J Constr Manag.* 2022;22(16):3148-57.
13. Tommelein I, Li A. *Just-in-Time Concrete Delivery: Mapping Alternatives for Vertical Supply Chain Integration.* s.l.: s.n.; 1999.