

SMART

Journal of Business Management Studies

(A Professional, Refereed, International and Indexed Journal)

Vol-22 Number-2

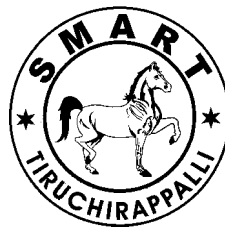
July - December 2026

Rs. 500

ISSN 0973-1598 (Print)

ISSN 2321-2012 (Online)

Professor MURUGESAN SELVAM, M.Com, MBA, Ph.D, D.Litt
Founder - Publisher and Chief Editor



**SCIENTIFIC MANAGEMENT AND ADVANCED RESEARCH TRUST
(SMART)**

TIRUCHIRAPPALLI (INDIA)

www.smartjournalbms.org

**MULTI-TIER VISIBILITY AND COLLABORATIVE RISK GOVERNANCE
AS DRIVERS OF PROJECT SUPPLY CHAIN RESILIENCE IN
MALAYSIA - A PROJECT MANAGEMENT PERSPECTIVE**

Premkumar Rajagopal

*Malaysia University of Science and Technology,
Petaling Jaya, Selangor, Malaysia
premkumar@must.edu.my*

Irwan Ibrahim

*RIG – Sustainable Supply Chain Logistics / Faculty of Business and Management,
Universiti Teknologi MARA Selangor, Malaysia
irwan623@uitm.edu.my*

N. Sureshkumar PP Narayanan

*University of East London, London, England
nsureshk@yahoo.com*

Fadhlur Rahim Azmi

*Faculty of Business & Management, Universiti Teknologi MARA (UiTM), Cawangan Melaka,
Kampus Bandaraya, Melaka, Malaysia.
fadhlur@uitm.edu.my*

Li Lian Chew

*Binary Business School, Binary University, Selangor, Malaysia
lilian@binary.edu.my*

and

Veera Pandiyan Kaliani Sundram*

*RIG – Sustainable Supply Chain Logistics / Faculty of Business and Management, Universiti Teknologi
MARA Selangor, Malaysia / Institute of Business Excellence, Universiti Teknologi MARA, Shah Alam, Malaysia
veera692@uitm.edu.my*

*** Corresponding Author**

Abstract

This study examines how Project Supply Chain Resilience (PSCR) in Malaysia is influenced by Multi-Tier Supply Chain Visibility (MSCV) and Collaborative Risk Governance (CRG) in project-based supply chains, where disruptions frequently cascade through multi-party handoffs and interdependencies. Drawing on resilience and information-processing logic, MSCV is expected to strengthen resilience by improving early warning capability and speeding up exception resolution across tiers. CRG is expected to strengthen resilience through shared risk routines, escalation rules, and coordinated mitigation across client-contractor-supplier interfaces, aligned with structured risk management principles (International Organization for Standardization). Using a quantitative survey approach and multivariate analysis, the study contributes a parsimonious project-management framework that translates resilience into two actionable levers-visibility and governance-relevant to Malaysian project supply chains.

Keywords: *Project supply chain, resilience, multi-tier visibility, collaborative risk governance, disruption management, project management*

JEL Code : *D81 and O53*

Paper Received : *02.02.2026*

Revised : *18.02.2026*

Accepted : *19.03.2026*

1. Introduction

Malaysia's project-based supply chains (e.g., construction and EPC projects) are increasingly exposed to disruption because delivery depends on sequenced handoffs across multi-tier suppliers and subcontractors, where a single upstream delay can cascade into idle resources, resequencing and claims (ISO, 2020; Guo et al., 2025; Muhammad et al., 2025; Munir et al., 2021). Malaysia's agenda acknowledges this vulnerability and hence the Construction 4.0 Strategic Plan (2021–2025) calls for integrated technologies and collaboration, and the National Construction Policy 2030 promotes sector-wide digitalisation to raise reliability and competitiveness (CIDB, 2021; Ministry of Works Malaysia, 2021). However, many projects still face Tier-2/Tier-3 opacity and fragmented risk ownership across contracting parties, which slows detection and response and weakens resilience (CIDB, 2021; Christopher & Peck, 2004).

To close this gap, this study tests how Multi-Tier Supply Chain Visibility (MSCV) and

Collaborative Risk Governance (CRG) influence Project Supply Chain Resilience (PSCR) in Malaysia (Jia et al., 2025; Alzate Rendón et al., 2025). MSCV is expected to strengthen early warning by improving the timeliness and accuracy of upstream constraint information while CRG is expected to accelerate coordinated action through shared escalation rules, decision rights and mitigation playbooks across firms (Jia et al., 2025; ISO, 2018). The contribution is a parsimonious, project-management-relevant framework, that translates policy and standards into two levers, for building resilience in Malaysian project supply chains (CIDB, 2021; ISO, 2020).

2. Literature Review

2.1. Project management and project supply chain context

Project delivery in Malaysia relies on temporary, tightly scheduled supply networks that link clients, main contractors, subcontractors, and upstream suppliers and hence disruptions can cascade into delays, rework, and cost escalation (Shishehgharkhaneh et al., 2024;

Ding et al., 2025; Sivan et al., 2026). Malaysia's National Construction Policy (NCP 2030) and the Construction 4.0 Strategic Plan both emphasise digitalised coordination and interoperable workflows across the delivery chain, increasing the managerial need for shared, near-real-time status information across tiers for complex, multi-actor project decisions, everyday (CIDB, 2023; CIDB, 2021). These digitalisation priorities align with evidence that Industry 4.0 can improve resilience at scale when information processing capability matches uncertainty and partner alignment (Daud et al., 2024b; Spieske et al., 2023).

2.2. Project Supply Chain Resilience [PSCR]

Supply chain resilience is commonly defined as the capability to anticipate, absorb, recover and adapt under disruption. Recent critical reviews position it as a dynamic capability built through sensing, seizing and reconfiguring routines (Shekarabi et al., 2025). In project supply chains, sequential interdependencies mean late or non-conforming deliveries can trigger critical-path slippage and claims and hence managers should build risk-mitigation frameworks and coordination practices to protect time and cost outcomes under uncertainty (Ding et al., 2025; Shishehgharkhaneh et al., 2024). Risk-management automation and data-driven monitoring are increasingly discussed as complements to resilience routines because they shorten detection and response cycles (Emrouznejad et al., 2023).

2.3. Multi-tier Supply Chain Visibility [MSCV]

Multi-tier supply chain visibility refers to timely, accurate and shareable information on inventories, capacities, shipments, constraints and risk signals beyond tier-1 partners, enabling earlier detection and coordinated response (Delgado et al., 2025). Organisational information processing theory predicts that richer visibility

reduces uncertainty, improves decision quality and accelerates response, which empirically strengthens resilience in disruption-prone networks (Jia et al., 2025). Recent systematic review evidence indicates multi-tier visibility to improve coordination and detect earlier problem surfacing in projects, supporting proactive mitigation rather than reactive expediting (Delgado et al., 2025; Ding et al., 2025).

2.4. Collaborative Risk Governance [CRG]

Collaborative risk governance captures cross-organisational mechanisms, that align incentives and behaviours through contractual controls (roles, penalties, risk-sharing clauses) and relational norms (trust and joint problem solving), rather than isolated firm-level risk management (Wu et al., 2023). Evidence shows contractual and relational governance improve resilience partly via stronger collaboration, and institutional conditions can amplify or dampen these effects (Wu et al., 2023). ISO 31000 reinforces this logic by emphasising defined responsibilities, structured risk processes and ongoing communication across stakeholders (ISO, 2018; Emrouznejad et al., 2023).

3. Statement of Problem

Malaysia's project supply chains are disruption-prone and sequenced handoffs across multi-tier suppliers lead to material delays, cascading into resequencing and claims (ISO, 2020). Tier-2/Tier-3 opacity and fragmented risk ownership across client-contractor-supplier interfaces slow detection and coordinated response (CIDB, 2021; Christopher & Peck, 2004). Although resilience is discussed, evidence is manufacturing centred and firm-level, leaving Malaysian project contexts under-tested (Shekarabi et al., 2025; Shishehgharkhaneh et al., 2024). This weakens guidance despite Malaysia's digitalisation agenda (CIDB, 2023).

Therefore, it remains unclear whether multi-tier visibility and collaborative risk governance jointly explain project supply chain resilience in Malaysia (Jia et al., 2025; Wu et al., 2023).

4. Need of the Study

Despite consensus that visibility and governance matter, much empirical evidence remains manufacturing-centred and firm-level, leaving Malaysian project supply chains under-tested, with a parsimonious model that project managers can operationalise (Shekarabi et al., 2025; Shishehgharkhaneh et al., 2024). Given Malaysia's policy push toward digitally integrated delivery ecosystems, testing whether multi-tier visibility and collaborative risk governance explain project supply chain resilience, is timely for both theory and practice (CIDB, 2023; CIDB, 2021).

5. Objective of the study

As shown in **Figure 1**, this study examined how Project Supply Chain Resilience (PSCR) in Malaysia was influenced by Multi-Tier Supply Chain Visibility (MSCV) and Collaborative Risk Governance (CRG). Specifically, it wanted to find out whether MSCV strengthens PSCR by improving disruption sensing and response speed and whether CRG strengthens PSCR through shared escalation rules and coordinated mitigation routines. Thus the study focused on client–contractor–supplier interfaces where multi-tier opacity and fragmented decision rights can amplify project shocks under disruption.

6. Hypotheses of the Study

In Malaysia's project-based supply chains, shocks often break out because upstream capacity, shipment status, and quality risks are opaque beyond Tier-1 suppliers (Narayanan et al., 2024b; Vatumalae et al., 2023). Multi-Tier Supply Chain Visibility (MSCV)-the ability

to track materials and related information across multiple tiers—reduces information asymmetry, improves early risk detection, and supports timely replanning/expediting, which are core mechanisms of resilience (Jia et al., 2025; Tukamuhabwa et al., 2015). Classic resilience work also argues that more open information flows within and between organisations, helps mitigate supply chain risk in complex networks (Christopher & Peck, 2004; Daud et al., 2024a). Evidence from industrial construction links visibility to better coordination and risk management across owners, contractors, and suppliers (Dharmapalan et al., 2025).

H1: Multi-Tier Supply Chain Visibility (MSCV) positively influences Project Supply Chain Resilience (PSCR) in Malaysia

Executive Resilience also depends on how partners jointly govern uncertainty. Collaborative Risk Governance (CRG)—shared risk registers, joint escalation rules, transparent performance reviews, and a mix of contractual and relational governance—clarifies decision rights and accelerates coordinated responses, reducing delays and blame shifting when disruptions occur (Christopher & Peck, 2004; Syakirah et al., 2020; Narayanan et al., 2024c). This aligns with risk-management guidance that embeds communication, monitoring, and continual improvement into governance (International Organization for Standardization [ISO], 2018). Empirical evidence shows cross-organizational governance strengthens supply chain resilience, partly through collaboration (Wu et al., 2023)

H2: Collaborative Risk Governance (CRG) positively influences Project Supply Chain Resilience (PSCR) in Malaysia

7. Research Methodology

This study adopted a quantitative, cross-sectional survey design, to test the effects of Multi-Tier Supply Chain Visibility (MSCV) and Collaborative Risk Governance (CRG) on Project Supply Chain Resilience (PSCR) in Malaysia's project-based supply chains. The unit of analysis was the project and one knowledgeable respondent (e.g., project manager, contract manager, procurement/logistics lead, or resident engineer) reported on the most recently completed project or major phase. A project-level lens is appropriate because project management guidance is intended to be applicable across project types and delivery approaches, enabling comparability of practices and outcomes across different project contexts (**International Organization for Standardization [ISO], 2020**).

7.1. Sampling Selection

This study employed a purposive, stratified sampling strategy, focused on Malaysian construction and infrastructure project supply chains. The target population consisted of Grade G6–G7 main contractors, key consultants, and Tier-1 suppliers involved in active or recently completed projects. Contractors, undertaking construction work in Malaysia, are required to register with the Construction Industry Development Board (CIDB), which supports the use of CIDB registration channels as a practical sampling frame for reaching eligible firms and key project actors (**CIDB, n.d.**). CIDB materials also describe contractor grades (G1–G7) and link grades to tendering capacity, which supports stratification by contractor capability level (**CIDB, n.d.**). The sampling frame was supplemented by using the Department of Statistics Malaysia's Interactive Malaysia Statistical Business Register (i-MSBR), to widen the coverage of upstream suppliers and reduce

“missing supplier” bias from relying only on contractor lists (Department of Statistics Malaysia [**DOSM**], **n.d.**). As shown in **Table-1**, stratification was applied by actor group (contractor/consultant/supplier), and the study proposed to collect approximately 260 usable responses, to support stable multiple-regression estimation and meaningful subgroup representation (**Pallant, 2020**).

7.2. Sources of Data

Primary data were collected via a structured online questionnaire, comprising closed-ended items, measured on a 7 - point Likert Scale (1= strongly disagree to 7 = strongly agree). The instrument measured: (i) MSCV (timely and accurate multi-tier status information on orders, shipments, inventories, constraints, and exceptions beyond Tier-1), (ii) CRG (shared risk registers, escalation thresholds, decision rights, and jointly agreed mitigation playbooks across project partners), and (iii) PSCR (capability to anticipate, absorb, recover, and adapt supply disruptions while protecting key milestones and critical deliverables). CRG items were phrased to reflect structured risk governance principles, consistent with ISO 31000 (**ISO, 2018**). The questionnaire also captured controls for project complexity, project type, firm size, and procurement mode, to reduce omitted-variable bias and improve interpretability of regression coefficients (**Pallant, 2020**).

7.3. Period of the Study

Data collection and analysis were conducted over six months. The first three months covered recruitment and follow-ups across strata while the remaining months covered data cleaning, diagnostics, and hypothesis testing, to support robust reporting (**Pallant, 2020**).

7.4. Tools used in the Study

IBM SPSS Statistics was used for descriptive statistics, reliability analysis

(Cronbach's alpha), correlations, and hierarchical multiple regression to estimate MSCV and CRG effects on PSCR while accounting for controls (Pallant, 2020). Microsoft Excel was used for preliminary coding, missing-value screening, and consistency checks before importing the dataset into SPSS (Field, 2024).

8. Data Analysis

Data were analysed in IBM SPSS Statistics. The study conducted (i) descriptive statistics to profile respondents and project characteristics, (ii) reliability testing (Cronbach's α) to assess internal consistency of the multi-item constructs, (iii) Pearson correlations to examine bivariate associations among variables and provide an initial check for collinearity, and (iv) hierarchical multiple regression with Project Supply Chain Resilience (PSCR) as the dependent variable. In the regression, the control variables (project complexity, firm size, project type, and procurement mode) were entered in Block 1, followed by the two predictors—Multi-Tier Supply Chain Visibility (MSCV) and Collaborative Risk Governance (CRG)—entered in Block 2, to test their incremental explanatory power over and above the controls.

8.1 Demographic Profile of Project Supply Chain Firms

A total of 260 valid responses were analysed to describe the sample profile, using descriptive statistics (Pallant, 2020). As presented in Table-2, 45.4% of respondents were from main contractors ($n = 118$), followed by consultants (35.4%, $n = 92$) and Tier-1 suppliers (19.2%, $n = 50$). The projects were mainly building projects (64.6%, $n = 168$) compared with infrastructure projects (35.4%, $n = 92$). In terms of procurement, 54.6% were privately procured ($n = 142$) while 45.4% were public projects ($n = 118$). Firm size was concentrated in the mid-range, with 50–199 employees

forming the largest group (47.7%, $n = 124$), followed by <50 employees (32.3%, $n = 84$) and ≥ 200 employees (20.0%, $n = 52$). Regarding firm age, 48.5% were established >10 years ($n = 126$), 30.0% between 5–10 years ($n = 78$), and 21.5% for <5 years ($n = 56$).

8.2 Reliability Test of Multi-Tier Supply Chain Visibility, Collaborative Risk Governance, and Project Supply Chain Resilience

Table-3 reports Cronbach's alpha (α) for the three multi-item scales. Multi-Tier Supply Chain Visibility (MSCV) recorded $\alpha = 0.86$, indicating very good internal consistency. Collaborative Risk Governance (CRG) reported $\alpha = 0.82$, reflecting good reliability. The dependent variable, Project Supply Chain Resilience (PSCR) (6 items), reported $\alpha = 0.89$, indicating excellent reliability. Since all α values exceeded the commonly accepted 0.70 threshold, the measures were considered reliable for subsequent correlation and regression analyses (Hair et al., 2019; Nunnally & Bernstein, 1994). Item–total diagnostics (not shown) revealed corrected item–total correlations ≥ 0.49 , and “ α if item deleted” did not exceed the reported α values and hence no items were removed.

8.3 Correlation Test of Multi-Tier Supply Chain Visibility, Collaborative Risk Governance, and Project Supply Chain Resilience

Pearson correlation analysis was conducted, to examine the bivariate relationships among Multi-Tier Supply Chain Visibility (MSCV), Collaborative Risk Governance (CRG), Project Supply Chain Resilience (PSCR), and the control variables (project complexity, firm size, project type, procurement mode) prior to multiple regression (Field, 2024; Pallant, 2020). As shown in Table 4, MSCV was positively and

significantly correlated with PSCR ($r = 0.45$, $p < 0.001$) while CRG was also positively and significantly correlated with PSCR ($r = 0.39$, $p < 0.001$), providing preliminary support for H1 and H2. MSCV and CRG were moderately correlated ($r = 0.42$, $p < 0.001$), which was expected because visibility can enable shared risk routines. But this value was less than levels commonly considered problematic for multicollinearity screening (Field, 2024).

For the controls, project complexity was negatively correlated with PSCR ($r = 0.27$, $p < 0.001$), consistent with the expectation that more complex projects would face greater disruption exposure and coordination burden (Pallant, 2020). Firm size showed small positive association with PSCR ($r = 0.12$, $p = 0.048$). Project type (1 = infrastructure) showed a small positive correlation with PSCR ($r = 0.14$, $p = 0.021$) while procurement mode (1 = public) had reported small negative and non-significant correlation ($r = 0.09$, $p = 0.136$). These results justified proceeding to hierarchical regression, with controls entered first (Field, 2024; Pallant, 2020).

8.4 Hierarchical Multiple Regression Predicting Project Supply Chain Resilience (PSCR)

Hierarchical multiple regression was conducted in IBM SPSS, to test whether Multi-Tier Supply Chain Visibility (MSCV) and Collaborative Risk Governance (CRG) significantly predicted Project Supply Chain Resilience (PSCR) in Malaysia, after controlling for project and firm characteristics (Field, 2024; Pallant, 2020). In Model 1, the control variables (project complexity, firm size, project type, procurement mode) explained 10.2% of the variance in PSCR ($R^2 = 0.102$, $p < 0.001$). After adding MSCV and CRG in Model 2, the explained variance increased to 28.1% ($R^2 =$

0.281), indicating a significant improvement ($\Delta R^2 = 0.179$, ΔF significant at $p < 0.001$), consistent with guidance that incremental variance would support substantive model contribution (Hair et al., 2019; Pallant, 2020).

As shown in Table-5, both predictors were positive and significant, with MSCV ($\beta = 0.31$, $p < 0.001$) and CRG ($\beta = 0.24$, $p < 0.001$), indicating that stronger multi-tier transparency and stronger cross-organizational risk routines were associated with higher resilience. Among controls, project complexity showed negative significant relationship with PSCR ($\beta = -0.18$, $p = 0.002$), implying that more complex projects could face greater resilience strain without compensating capabilities (Field, 2024). Multicollinearity was not a concern (all VIF < 1.70) and residual independence were acceptable (Durbin-Watson = 2.01), supporting the suitability of the regression estimates (Field, 2024; Pallant, 2020).

9. Findings and Discussion

9.1 Multi-Tier Supply Chain Visibility

The regression results revealed that Multi-Tier Supply Chain Visibility (MSCV) was positively and significantly associated with Project Supply Chain Resilience (PSCR) even after controlling for project complexity, firm size, project type, and procurement ($\beta = 0.31$, $p < 0.001$). In other words, resilience in project supply chains was not just about having more resources, but it was about having earlier, clearer, and wider visibility across tiers, so that project teams can detect upstream constraints sooner, resolve exceptions faster, and replan schedules/material flows with less delay. This interpretation was consistent with organizational information processing logic, showing that visibility improved resilience under uncertainty. It also aligned with construction/project evidence that visibility would support material coordination

and risk mitigation across multiple stakeholders (Sivan et al., 2023).

9.2 Collaborative Risk Governance

Collaborative Risk Governance (CRG) was also positively related to PSCR beyond the control variables ($\beta = 0.24, p < 0.001$). Practically, this indicated that projects with shared risk routines, joint risk registers, agreed escalation thresholds, clarified decision rights, and pre-agreed mitigation playbooks could coordinate faster and lose less time during disruptions. This was consistent with risk-management guidance, that emphasizes structured processes, communication and continuous monitoring across organizational boundaries. The finding was also consistent with evidence that cross-organizational governance (contractual + relational) strengthens resilience through collaboration mechanisms.

9.3 Joint Effect Robustness

When MSCV and CRG were entered together, explanatory power increased from $R^2 = 0.102$ (controls only) to $R^2 = 0.281$, with $\Delta R^2 = 0.179$ ($p < 0.001$). The moderate MSCV–CRG association ($r = 0.42, p < 0.001$) indicated complementarity visibility improved information, while governance improved decision speed and coordination needed for resilience in complex projects. This “visibility + governance” logic was consistent with established resilience thinking in supply chains. In Malaysia, this direction could fit the policy push toward integrated technologies and governance across the construction supply chain, highlighted by Construction Industry Development Board Malaysia.

10. Suggestion

First, Malaysian project organisations should prioritise multi-tier visibility for the small set of items, that can “kill the schedule” (long-lead, high-value, single-source, or compliance-sensitive materials). In other words, extending

tracking beyond Tier-1 to Tier-2/Tier-3 constraints (capacity, subcomponents, shipment milestones, and customs/compliance status) and enforcing timely exception reporting, visibility improved resilience through better information quality and faster response (Jia et al., 2025; Christopher & Peck, 2004). Second, visibility must be paired with collaborative risk governance and not ad-hoc meetings. Projects should implement a shared risk register, agreed trigger thresholds, named risk owners, and a clear escalation path, with decision rights across client–contractor–supplier interfaces, because cross-organisational governance strengthens resilience via collaboration mechanisms (Wu et al., 2023; ISO, 2018). Third, contracts and project governance should include resilience KPIs (e.g., critical item OTIF, exception resolution time, recovery lead time, and substitution approval cycle time) and review them on a fixed cadence, consistent with structured risk management principles (ISO, 2018). Finally, these actions align with Malaysia’s Construction 4.0 direction, which emphasises ecosystem integration and capability building across the construction supply chain (CIDB Malaysia, 2021; Dharmapalan et al., 2025). If these controls are not institutionalised, teams will revert to firefighting and expediting, which looks “busy” but does not build resilience.

11. Conclusion

This study concludes that Multi-Tier Supply Chain Visibility (MSCV) and Collaborative Risk Governance (CRG) are both significant drivers of Project Supply Chain Resilience (PSCR) in Malaysia’s project-based supply chains. The findings support the view that resilience is built through two complementary capabilities: (i) seeing disruption risks early across tiers through stronger visibility, and (ii) responding quickly through shared governance routines that

coordinate decisions across organisations (**Jia et al., 2025; Wu et al., 2023**). The results also reinforce foundational resilience arguments that information sharing and coordinated action could reduce disruption impact and improve recovery in complex networks (**Christopher & Peck, 2004; Narayanan et al., 2024a; Sivan et al., 2022**). Practically, the message is straightforward. Projects that invest only in tracking, without governance, will still be slow to act while projects with governance but weak upstream visibility will act too late. Malaysia's Construction 4.0 policy direction makes this pairing especially timely (**CIDB Malaysia, 2021**).

12. Limitation of Study

There are four clear limitations. First, the research design was cross-sectional and the results supported association rather than causality. (**Pallant, 2020; Field, 2024**). Second, the measures relied on single-respondent self-report, which can introduce common method bias. Future work should triangulate with objective indicators such as OTIF for critical items, days of schedule slippage attributable to supply issues, and resolution cycle times for exceptions (**Ali et al., 2020; Field, 2024; Vatumalae et al., 2022**). Third, the sample was framed within Malaysia's project supply chain context (primarily construction-related actors), which may limit generalisability to other project industries (e.g., oil and gas turnarounds, shipbuilding, or IT programs) where governance structures differ (**ISO, 2020**). Fourth, the model was intentionally parsimonious (two predictors) and other relevant drivers like supplier concentration, contractual risk-sharing design, digital platform maturity, or disruption type were not explicitly tested and may explain additional variance in PSCR (**Wong et al., 2024; Wu et al., 2023; Christopher & Peck, 2004**).

13. Scope for Further Research

Future research can strengthen and extend this study in five clear directions. First, researchers could use longitudinal and event-based designs, to test causality by tracking disruption episodes (e.g., late shipment, quality nonconformance, customs delay) and measuring whether Multi-Tier Supply Chain Visibility (MSCV) reduces detection time and Collaborative Risk Governance (CRG) reduces recovery time, which cannot be confirmed with cross-sectional data. Second, studies could triangulate survey perceptions with objective resilience metrics such as critical-item OTIF, exception resolution cycle time, resequencing days, and disruption-attributed schedule slippage to reduce common method bias. Third, researchers could test boundary conditions by examining whether the MSCV–PSCR and CRG–PSCR relationships differ across procurement settings (public vs. private), project types (building vs. infrastructure), and project complexity levels because governance and visibility mechanisms often behave differently under different institutional and contractual environments. Fourth, future models could incorporate additional predictors (e.g., supplier concentration risk, contractual risk-sharing design, digital platform maturity, or supply chain redundancy) that have been linked to resilience in broader supply chain literature (**Narayanan et al., 2025; Rasi et al., 2021**). Finally, comparative studies across ASEAN countries, could test whether Malaysia's findings could be generalised to similar emerging-market project ecosystems, improving external validity and regional relevance.

14. Acknowledgements

We express our sincere appreciation to the Malaysian Ministry of Education and Universiti Teknologi MARA, Shah Alam, for their

indispensable assistance in facilitating the execution of this research project.

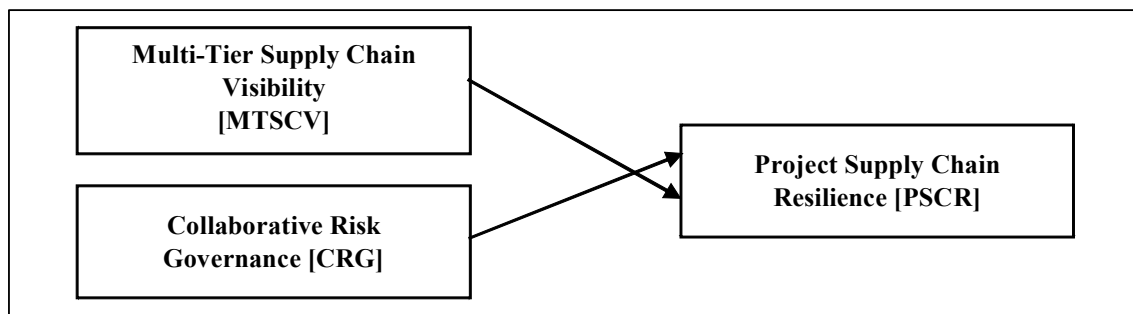
15. References

- Ali, S.N.R., Rajagopal, P., Sundram, V.P.K., Saihani, S.B., & Noranee, S. (2020).** ERP System Implementation in a Leading LED Manufacturing in Malaysia: A Supply Chain Perspective. *International Journal of Supply Chain Management*, 9(2), 104.
- Alzate Rendón, I. C., Álvarez Gallo, S. M., & Boada, A. (2025).** Supply chain resilience through collaborative networks and dynamic capabilities: Evidence from an agri-food productive chain in Colombia. *Discover Sustainability*, 6, 1312. <https://doi.org/10.1007/s43621-025-02094-9>
- Christopher, M., & Peck, H. (2004).** Building the resilient supply chain. *The International Journal of Logistics Management*, 15(2), 1-14. <https://doi.org/10.1108/09574090410700275>
- CIDB Malaysia. (2021).** *Construction 4.0 Strategic Plan (2021-2025)*. Construction Industry Development Board Malaysia.
- CIDB Malaysia. (2023).** *National Construction Policy (NCP 2030)*. Construction Industry Development Board Malaysia.
- Construction Industry Development Board Malaysia (CIDB). (n.d.).** *Contractor Registration – Pendaftaran Kontraktor*.
- Construction Industry Development Board Malaysia. (2020).** *Construction 4.0 strategic plan (2021–2025): Next revolution of the Malaysian construction industry*. CIDB Malaysia
- Construction Industry Development Board Malaysia. (2021).** *Construction 4.0 Strategic Plan (2021–2025)*.
- Daud, A., Narayanan, N. S. P. P., Ghapar, F., Chew, L. L., Sundram, V. P. K., Naidu, B.M. & Zulfakar, M. H. (2024a).** Artificial Intelligence-Powered Risk Assessment in Supply Chain Safety. *Information Management and Business Review*, 16(3S(a)), 107-114.
- Daud, A., Narayanan, N. S. P. P., Ghapar, F., Chew, L. L., Sundram, V. P. K., & Naidu, B. M. (2024b).** Integrating Resource-Based Theory and Contingency Theory for Enhancing Supply Chain Resilience in Malaysia: A Post-Pandemic Analysis. *Information Management and Business Review*, 16(3S(a)), 115-124.
- Delgado, A., et al. (2025).** Supply chain visibility: A systematic literature review of barriers and future research opportunities. *Sustainability*, 17. doi:10.3390/su17125097
- Department of Statistics Malaysia (DOSM). (n.d.).** *Interactive Malaysia Statistical Business Register (i-MSBR)*.
- Dharmapalan, V., O'Brien, W. J., & Morrice, D. (2025).** Benefits of visibility in industrial construction projects: Supply chain stakeholders' perspectives. *Frontiers in Built Environment*, 11, 1698777. doi:10.3389/fbuil.2025.1698777.
- Ding, M. J., & Jie, F. (2025).** Mitigating the supply chain uncertainties and risks in the construction projects: Case studies of Australian construction projects. *Cleaner Logistics and Supply Chain*, 100237. doi:10.1016/j.clscn.2025.100237
- Emrouznejad, A., et al. (2023).** Supply chain risk management automation: A literature review. *Supply Chain Analytics*, 2, 100031. doi:10.1016/j.sca.2023.100031
- Field, A. (2024).** *Discovering statistics using IBM SPSS statistics* (6th ed.). SAGE.
- Guo, Y., Liu, F., Song, J.-S., & Wang, S. (2025).** Supply chain resilience: A review from the inventory management perspective. *Fundamental Research*, 5(2), 450–463. <https://doi.org/10.1016/j.fmre.2024.08.002>
- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019).** *Multivariate data analysis* (8th ed.). Cengage.

- International Organization for Standardization (ISO). (2018).** *ISO 31000:2018 Risk management— Guidelines*.
- International Organization for Standardization (ISO). (2020).** *ISO 21502:2020 Project, programme and portfolio management — Guidance on project management*.
- International Organization for Standardization. (2018).** *ISO 31000:2018 Risk management-Guidelines* (2nd ed.). ISO.
- International Organization for Standardization. (2020).** *ISO 21502:2020 Project, programme and portfolio management-Guidance on project management* (1st ed.).
- Jia, F., Hu, Q., & Chen, L. (2025).** The impact of supply chain visibility on resilience performance: The role of improved decision quality and response speed. *Transportation Research Part E: Logistics and Transportation Review*, 104428. doi:10.1016/j.tre.2025.104428
- Ministry of Works Malaysia. (2021).** *National Construction Policy 2030 (NCP 2030)*.
- Muhammad, S. H. M., Narayanan, N. S. P. P., Ghapar, F., Chew, L. L., & Sundram, V. P. K. (2025).** *The impact of good citizenship dimensions on supply chain sustainability*. SMART Journal of Business Management Studies, 21(1), 26–37.
- Munir, Z. A., Bhatti, M. A., & Sundram, V. P. K. (2021).** The determinants of humanitarian supply chain efficiency-a case study of flood disaster in Malaysia. *SMART Journal of Business Management Studies*, 17(2), 10-16.
- Narayanan, N. S. P. P., Ghapar, F., Chew, L. L., & Rahim, F. (2025).** *Leveraging digital twins for project management success in supply chain environments*. SMART Journal of Business Management Studies, 21(2), 26–39.
- Narayanan, N. S. P. P., Ghapar, F., Chew, L. L., Sundram, V. P. K., & Jayamani, U. (2024a).** Measuring the unmeasured: Exploring the concept of “Supply Chain Quotient” [SCQ]. *Information Management and Business Review*, 16(2I), 36-43.
- Narayanan, N. S. P. P., Ghapar, F., Chew, L. L., Sundram, V. P. K., & Jayamani, U. (2024b).** Optimizing working capital management in supply chain finance: A multi-dimensional approach. *Information Management and Business Review*, 16(2I), 44-52.
- Narayanan, N. S., Fathurahman, H., Ahmad, N. N., Ghapar, F., Chew, L. L., & Sundram, V. P. K. (2024c).** Consumer Perspectives on the Sustainability of the Malaysian Palm Oil Supply Chain: Awareness, Price Sensitivity, and Certification Impacts. *Malaysian Journal of Consumer and Family Economics* 33, 408-436.
- Nunnally, J. C., & Bernstein, I. H. (1994).** *Psychometric theory* (3rd ed.). McGraw-Hill.
- Pallant, J. (2020).** *SPSS survival manual: A step by step guide to data analysis using IBM SPSS* (7th ed.). Routledge.
- Rasi, R. Z., Rakiman, U., Radzi, R. Z. R. M., Masrom, N. R., & Sundram, V. P. K. (2021).** A Literature Review on Blockchain Technology: Risk in Supply Chain Management. *IEEE Engineering Management Review*, 50(1), 186-200.
- Shekarabi, S. A. H., et al. (2025).** Supply chain resilience: A systematic literature review and a research agenda. *Annals of Operations Research*. doi:10.1007/s10479-025-06284
- Shishehgarkhaneh, H., et al. (2024).** Construction supply chain risk management: Systematic literature review and future research agenda. *Automation in Construction*, 105396. doi:10.1016/j.autcon.2024.105396
- Sivan, S., Chew LL., Ghapar, F., Sundram, VPK and Munir, ZA. (2023).** The relationship between information technology and logistics integration: A case study of Malaysia’s logistics and distribution industry, *SMART Journal of Business Management Studies* 19 (2), 1-11.

- Sivan, S., Ghadiri, S. M., Rajagopal, P., Atikah, S. B., & Sundram, V. P. K. (2022).** Adoption and Benefit of Industrial Revolution 4.0 in Logistics Industry: A Conceptual Paper. *Journal of Entrepreneurship, Business and Economics*, 10(2S1), 79-94.
- Sivan, S., Gharpar, F., Narayanan, N. S. P. P., Azmi, F. R., Chew, L. L., & Sundram, V. P. K. (2026).** Construction 4.0 readiness and project delivery performance in Malaysia: Roles of digital skills and top management support in the construction supply chain. *SMART Journal of Business Management Studies*, 22(1), 109–122. <https://doi.org/10.34293/2321-2012.2026.0001.9>
- Spieske, A., et al. (2023).** Industry 4.0 and supply chain resilience: A Delphi-based analysis. *Computers & Industrial Engineering*, 109344. doi:10.1016/j.cie.2023.109344
- Syakirah, N., Rajagopal, P., Sundram, V. P. K., Zuraidah, R. R., Ratna, M. N. & Zamry, G. (2020).** Achieving Supply Chain Excellence through Effective Supplier Management: A Case Study of a Marine Organisation. *International Journal of Supply Chain Management*, 9(4), 11-23.
- Tukamuhabwa, B. R., Stevenson, M., Busby, J., & Zorzini, M. (2015).** Supply chain resilience: Definition, review and theoretical foundations for further study. *International Journal of Production Research*, 53(18), 5592-5623. doi:10.1080/00207543.2015. 1037934
- Vatumalae, V., Rajagopal, P., Sundram, V. P. K., & Hua, Z. (2022).** A study of retail hypermarket warehouse inventory management in Malaysia. *SMART Journal of Business Management Studies*, 18(1), 71-79.
- Vatumalae, V., Rajagopal, P., Sundram, V. P. K., Zarina, A. M., and Gharpar, F. (2023).** Linking Factors Leading to Retail Hypermarket Warehouse Operations Performance in Malaysia, *SMART Journal of Business Management Studies* 19 (1), 1-9.
- Wong Chee, H., Sundram, V. P. K., Bakar, S. M. S. A., & Narayanan, N. S. P. P. (2024).** Charting a thriving path for the Malaysian palm oil supply chain: A SWOT-QSPM-powered strategic roadmap. *Journal of Distribution Science*, 22(10), 31–41.
- Wu, Q., Zhu, J., & Cheng, Y. (2023).** The effect of cross-organizational governance on supply chain resilience: A mediating and moderating model. *Journal of Purchasing and Supply Management*, 29(1), 100817. doi:10.1016/j.pursup.2023.100817.
- Wu, Z., et al. (2023).** Cross-organizational governance for supply chain resilience: Institutional conditions for contractual and relational governance. *Journal of Purchasing and Supply Management*, 100817. doi:10.1016/j.pursup.2023.100817

Figure 1: Conceptual Framework



Source: Framed by Authors

Table-1: Sampling Frame and Responses by Strata (Malaysia Construction Supply Chain)

Strata (Project Actor)	Sampling Frame (N)	Targeted Sample (n)	Responses (n)	Response rate (%)
Main contractor	320	240	118	57.5
Consultants	260	200	92	57.5
Tier-1 suppliers	180	160	50	45.0
Total	1760	600	325	54.2

Source: Generated by Authors

Table-2: Respondents' Profile

Category	Sub-category	Frequency	Percentage (%)
Respondent Type	Main contractor	118	45.4
	Consultant	92	35.4
	Tier-1 supplier	50	19.2
Project type	Building	168	64.6
	Infrastructure	92	35.4
Procurement Mode	Private	142	54.6
	Public	118	45.4
Firm size (employees)	< 50	84	32.3
	50–199	124	47.7
	= 200	52	20.0
Firm Age or Years established	< 5 years	56	21.5
	5–10 years	78	30.0
	> 10 years	126	48.5

Source: Primary data computed using SPSS

Table-3: Reliability Test of Multi-Tier Supply Chain Visibility, Collaborative Risk Governance and Project Supply Chain Resilience

Construct	Items	Example codes	Cronbach's α	Interpretation
Multi-Tier Supply Chain Visibility (MSCV)	4	MSCV1–MSCV4	0.86	Very good
Collaborative Risk Governance (CRG)	4	CRG1–CRG4	0.82	Good
Project Supply Chain Resilience (PSCR)	6	PSCR1–PSCR6	0.89	Excellent

Source: Primary data computed using SPSS

Table - 4: Correlation between Multi-Tier Supply Chain Visibility, Collaborative Risk Governance, and Project Supply Chain Resilience (Two-tailed; n = 260)

Variable	1	2	3	4	5	6	7
1. MSCV	—						
2. CRG	0.42***	—					
3. PSCR	0.45***	0.39***	—				
4. Project complexity	- 0.20**	- 0.16*	- 0.27***	—			
5. Firm size	0.14*	0.11	0.12*	0.18**	—		
6. Project type (0=Build,1=Infra)	0.12	0.09	0.14*	0.22***	0.10	—	
7. Procurement (0=Private,1=Public)	0.08	0.05	- 0.09	0.15*	0.06	0.21***	—

Notes: Pearson correlations. $p < 0.05$, $p < 0.01$, $p < 0.001$. Dummy-coded controls: project type (0=Build, 1=Infra) and procurement (0=Private, 1=Public). Computed in IBM SPSS Statistics following standard interpretation guidance (Discovering Statistics Using IBM SPSS Statistics; SPSS Survival Manual).

Table-5: Hierarchical Multiple Regression Predicting Project Supply Chain Resilience (PSCR)

Model	Predictor	β (Std.)	t	Sig.	VIF
Model 1	Project complexity	- 0.20	- 3.33	0.001	1.28
[Controls]	Firm size	0.08	1.45	0.148	1.22
	Project type [1 = Infrastructure]	- 0.11	2.15	0.032	1.14
	Procurement Mode [1 = Public]	- 0.09	- 1.77	0.078	1.10
Model 2	MSCV	0.31	5.77	<0.001	1.62
[Independent variables & Control variables]	CRG	0.24	4.46	<0.001	1.67
	Project complexity	- 0.18	- 3.12	0.002	1.33
	Firm size	0.07	1.33	0.185	1.24
	Project type [1 = Infrastructure]	0.09	1.88	0.061	1.16
	Procurement Mode [1 = Public]	- 0.07	- 1.52	0.130	1.12

Source: Primary data computed using SPSS

Model fit summary

Model 1: $R^2 = 0.102$; Adj. $R^2 = 0.088$; $F(4, 255) = 7.23$, $p < 0.001$

Model 2: $R^2 = 0.281$; Adj. $R^2 = 0.264$; $F(6, 253) = 16.44$, $p < 0.001$

Change : $\Delta R^2 = 0.179$; $\Delta F(2, 253) = 31.43$, $p < 0.001$

Durbin-Watson: 2.01