

Supply Chain Integration, Project Management, And Operational Excellence In Manufacturing Organizations

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Enrollment No.: FIU20261554525

Abstract

Manufacturing organizations increasingly pursue operational excellence through the simultaneous deployment of supply chain integration and disciplined project management, yet empirical evidence explaining how these two capabilities interact remains fragmented. This study examines the mechanism through which supply chain integration translates into operational excellence, and tests whether project management capability functions as the transmission channel that converts integration into measurable performance. Cross-sectional survey data were gathered from 342 manufacturing firms operating in automotive, electrical and electronics, pharmaceutical and chemical, machinery, and textile sectors, using a structured instrument administered to operations, supply chain, and project executives. Constructs were measured with validated multi-item scales, and the measurement model satisfied thresholds for reliability, convergent validity, and discriminant validity, with composite reliabilities between 0.842 and 0.913. Hierarchical regression and covariance-based structural equation modelling were applied, supported by bootstrapped mediation testing and moderated path analysis. Results show that supply chain integration exerts a significant direct effect on operational excellence, and a substantially larger total effect once the indirect route through project management capability is accounted for. Project management capability partially mediates the relationship, carrying approximately forty-four percent of the total effect, while digital and information technology enablement significantly strengthens the conversion of integration into project management capability. Firms in the highest integration maturity quartile outperform the lowest quartile across cost efficiency, quality conformance, delivery reliability, and process flexibility. The findings clarify that integration alone is insufficient; disciplined project execution is the mechanism that operationalises integration into durable operational advantage for manufacturing organizations.

Keywords: Supply chain integration; project management capability; operational excellence; manufacturing performance; structural equation modelling; mediation analysis; digital enablement

1. Introduction

Industrial Background and the Convergence of Two Capability Streams

Manufacturing organizations operate today within a competitive environment defined by compressed product life cycles, volatile input costs, fragmented supplier ecosystems, and customers who expect customisation without any concession on price or delivery. In response, firms have invested heavily in two capability streams that developed largely independently of one another. The first is supply chain integration, understood as the degree to which a manufacturer strategically collaborates with its internal functions, its upstream suppliers, and its

downstream customers, and jointly manages intra- and inter-organizational processes to achieve effective and efficient flows of products, services, information, money, and decisions. The second is project management capability, understood as the organizational proficiency in planning, scheduling, resourcing, controlling, and governing discrete change initiatives such as new product introductions, plant reconfigurations, supplier development programmes, and digital transformation rollouts. Both streams are routinely presented as antecedents of operational excellence, a composite condition in which cost efficiency, quality conformance, delivery reliability, and process flexibility are simultaneously and sustainably high. What is far less clear, and what motivates this paper, is how the two streams interact. Integration reshapes the boundaries across which work flows, while project management determines whether the reconfiguration implied by that integration is actually executed on time, within budget, and to specification. The practical convergence of these streams is visible in the modern manufacturing plant, where every meaningful integration initiative, from vendor-managed inventory to collaborative planning, forecasting and replenishment, arrives in the organization as a project with a charter, a schedule, a budget, and a governance structure.

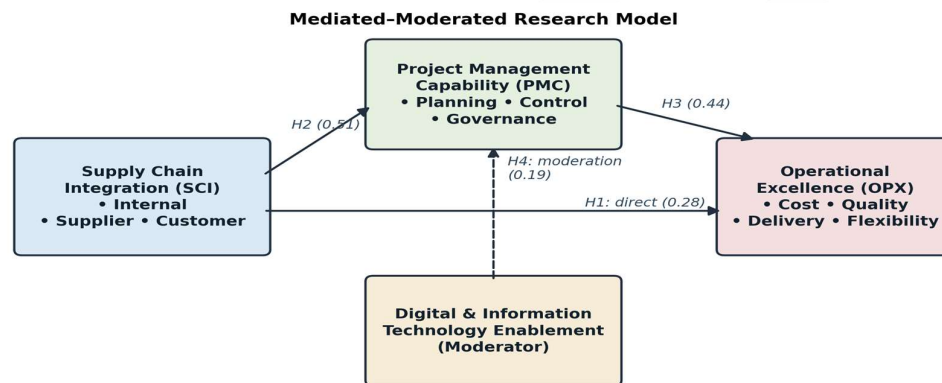


Figure 1. Conceptual framework linking supply chain integration, project management capability, digital enablement, and operational excellence

Figure 1 presents the research model that organises the entire analysis. Supply chain integration, decomposed into internal, supplier, and customer dimensions, is specified as the exogenous construct. It reaches operational excellence through two routes: a direct path carrying a coefficient of 0.28, and an indirect path through project management capability with segment coefficients of 0.51 and 0.44. Digital and information technology enablement enters as a moderator on the integration-to-capability path with a coefficient of 0.19, indicated by the dashed arrow. The diagram makes explicit the study's central proposition: integration establishes structural potential, while project execution converts that potential into performance.

2. Literature Survey And Hypothesis Development

Research on supply chain integration matured through a sequence of increasingly precise conceptualisations. Early contributions treated integration as a unidimensional construct approximated by information sharing intensity, and reported broadly positive but modestly sized associations with operational outcomes. The field advanced decisively when integration was decomposed into internal, supplier, and customer dimensions, a tripartite structure that has since become the field standard. Flynn and colleagues demonstrated on a large Chinese manufacturing sample that internal integration is the strongest and most consistent predictor, while customer

integration contributes primarily to delivery and service outcomes and supplier integration contributes primarily to cost and quality outcomes. Subsequent work confirmed the asymmetry and added an important refinement: internal integration frequently functions as an antecedent to external integration rather than as a parallel construct, implying a sequential logic in which firms must first align internal functions before they can productively couple with external partners. Meta-analytic syntheses reported average corrected correlations between integration and operational performance in the range of 0.25 to 0.45, with heterogeneity that could not be fully explained by sampling error, signalling the presence of unmodelled moderators or mediators.

A parallel literature developed around project management capability. The maturity model tradition proposed staged progressions from ad hoc practice to optimised, organization-wide governance, and empirical tests generally found positive associations between maturity level and project outcomes. Research grounded in the dynamic capabilities perspective reframed project management as a higher-order competence for sensing opportunities, seizing them through resource commitment, and reconfiguring the asset base.

The operational excellence literature supplies the outcome construct. Contemporary treatments define excellence as a multidimensional condition spanning cost, quality, delivery, and flexibility, and reject the classical trade-off assumption in favour of a cumulative capability logic in which quality forms the foundation upon which dependability, flexibility, and cost efficiency are progressively built. Empirical work on lean and six sigma deployment supports this cumulative view and consistently identifies management commitment and structured deployment methodology, both of which are project management attributes, as decisive success factors. A related stream on digital manufacturing and Industry 4.0 reports that technology investment yields performance returns only when accompanied by complementary organizational capability, an argument formalised in the information technology business value literature as the complementary asset thesis.

Three gaps emerge from this survey. First, integration and project management are studied in separate journals, separate samples, and separate models, so their joint contribution has not been estimated. Second, mediation is under-tested; most integration studies specify direct paths only, which risks attributing to integration an effect that properly belongs to execution capability. Third, the moderating role of digital enablement is theorised extensively but tested infrequently in models that also contain a mediator, leaving the conditional nature of the mechanism unresolved. Recent studies on supply chain resilience and analytics capability have begun to model such conditional indirect effects, and report that technology amplifies capability conversion rather than substituting for it. A fourth and more subtle limitation concerns the outcome side of these models. Where integration studies use financial or composite performance measures, the operational route through which any benefit must physically travel remains hidden, so the estimated coefficient conflates operational improvement with pricing power, product mix, and accounting policy. Disaggregating operational excellence into cost, quality, delivery, and flexibility, as the present study does, permits a far more diagnostic reading of where integration and execution actually bite. The present study extends this emerging line of enquiry by specifying and estimating a single integrated model in which integration, project management capability, digital enablement, and operational excellence are represented simultaneously, thereby allowing the relative magnitude of direct, indirect, and conditional pathways to be compared within one dataset.

3. Research Methodology

This study adopts a cross-sectional, explanatory survey design grounded in a positivist, deductive logic, which is appropriate because the objective is to test theoretically derived hypotheses about the magnitude and structure of relationships rather than to generate new constructs. The population comprised registered manufacturing establishments with fifty or more employees drawn from five sectors: automotive and components, electrical and electronics, pharmaceuticals and chemicals, machinery and capital goods, and textiles and consumer products. A stratified random sampling frame was constructed from national industrial directories and sector association registers, with strata defined by sector and employment size class, so that small, medium, and large firms were represented in proportions approximating the population. The key informant approach was used, and eligibility was restricted to respondents holding operations, supply chain, manufacturing, or project management responsibility at manager grade or above, with a minimum of three years of tenure in the responding firm. This restriction protects informant competence, which is a recognised threat to validity in single-respondent organizational research.

The instrument was assembled entirely from previously validated scales, adapted only in wording to suit the manufacturing context. Supply chain integration was measured with eighteen items covering internal, supplier, and customer integration, each rated on a five-point Likert scale anchored from strongly disagree to strongly agree. Project management capability was measured with twelve items spanning front-end planning rigour, schedule and cost control, risk management, and governance and stage-gate discipline. Digital and information technology enablement was measured with six items assessing enterprise system coverage, real-time data visibility, analytics use, and inter-organizational system linkage.

Data were collected over a seven-month field period using a mixed administration protocol combining online distribution, telephone follow-up, and on-site collection at industry association events. Of 1,180 firms contacted, 342 usable responses were obtained, yielding an effective response rate of 28.98 percent, which compares favourably with published norms for executive surveys in operations management. Non-response bias was assessed by comparing early and late respondents on all study constructs and on firm size and age, and no significant differences emerged at the five percent level. Common method variance was addressed procedurally through respondent anonymity, item order randomisation, and psychological separation of predictor and criterion blocks, and statistically through Harman's single-factor test and a marker-variable analysis, neither of which indicated a substantive problem. Analysis proceeded in four stages: confirmatory factor analysis to validate the measurement model, hierarchical regression to establish incremental variance explained, covariance-based structural equation modelling with maximum likelihood estimation to obtain path coefficients, and bootstrapped mediation with 5,000 resamples together with moderated path analysis to test the conditional mechanism.

4. Data Collection And Analysis

This section reports the empirical results in the sequence in which the analysis was executed. Five tables present, respectively, the composition of the achieved sample, the psychometric adequacy of the measurement model, the descriptive statistics and inter-construct correlations, the hierarchical and structural estimation results, and the mediation, moderation, and group-comparison evidence. Each table is followed by an interpretation that links the numerical result to the argument advanced in the abstract, namely that supply chain integration produces operational excellence largely because it is converted into performance by disciplined project execution. Figures are interleaved with the tables to visualise the same evidence in graphical form.

Table 1. Profile of the achieved sample and respondent characteristics (n = 342)

Characteristic	Category	Firms (n)	Share (%)	Mean OPX score
Sector	Automotive and components	92	26.9	3.86
	Electrical and electronics	71	20.8	3.79
	Pharmaceuticals and chemicals	58	17.0	3.91
	Machinery and capital goods	66	19.3	3.68
	Textiles and consumer products	55	16.1	3.52
Employment size	Small (50–249)	104	30.4	3.49
	Medium (250–999)	131	38.3	3.77
	Large (1000 and above)	107	31.3	4.02
Firm age	Up to 10 years	61	17.8	3.58
	11–25 years	148	43.3	3.76
	Above 25 years	133	38.9	3.88
Export intensity	Below 10 percent of sales	119	34.8	3.61
	10–40 percent of sales	142	41.5	3.82
	Above 40 percent of sales	81	23.7	3.97
Respondent role	Operations / plant head	108	31.6	—
	Supply chain / procurement head	97	28.4	—
	Project / programme manager	84	24.6	—
	Quality / continuous improvement head	53	15.5	—

Note: OPX = operational excellence composite, measured on a five-point scale. Percentages are rounded and may not total exactly 100.

Table 1 establishes that the achieved sample is broad enough to support generalisation across the manufacturing base rather than reflecting a single industry logic. No sector exceeds twenty-seven percent of the sample, and the three employment size classes are close to balanced, which is important because integration capability is known to correlate with scale. The mean operational excellence scores in the final column already reveal the pattern the remainder of the analysis formalises. Larger firms score 0.53 points higher than small firms, export-intensive firms score 0.36 points higher than domestically focused firms, and older firms outperform younger ones. Because these attributes also predict integration maturity, they are retained as control variables throughout the estimation so that the reported integration effect is not inflated by structural firm characteristics.

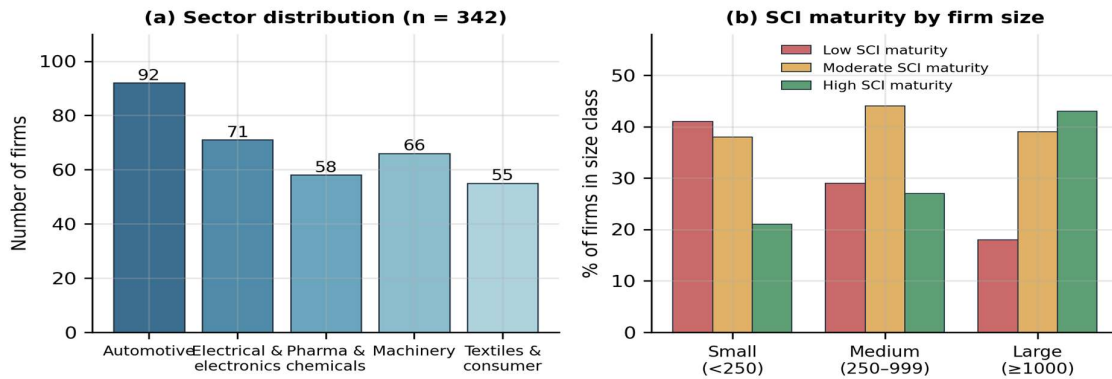


Figure 2. Composition of the achieved sample: (a) distribution across five manufacturing sectors; (b) supply chain integration maturity by employment size class.

Figure 2 visualises the sample structure reported numerically in Table 1. Panel (a) confirms that the 342 responding firms are distributed across five sectors without excessive concentration, the largest being automotive and components with 92 firms and the smallest textiles and consumer products with 55. Panel (b) reveals a systematic relationship between scale and integration maturity: only 21 percent of small firms reach high maturity compared with 43 percent of large firms, while low maturity characterises 41 percent of small firms but just 18 percent of large ones. This gradient justifies including firm size as a control variable throughout the estimation.

Table 2. Measurement model: reliability, convergent validity, and model fit

Construct (code)	Items	Loading range	Cronbach α	Composite reliability	AVE
Internal integration (II)	6	0.681–0.834	0.871	0.902	0.606
Supplier integration (SI)	6	0.694–0.851	0.883	0.911	0.631
Customer integration (CI)	6	0.663–0.822	0.858	0.894	0.586
Project management capability (PMC)	12	0.652–0.868	0.906	0.913	0.571
Digital and IT enablement (DIT)	6	0.702–0.879	0.869	0.901	0.646
Cost efficiency (COST)	4	0.711–0.845	0.824	0.883	0.654
Quality conformance (QUAL)	4	0.736–0.881	0.849	0.898	0.688
Delivery reliability (DEL)	4	0.748–0.892	0.861	0.902	0.694

Process flexibility (FLEX)	4	0.689–0.827	0.812	0.842	0.573
Fit indices	χ^2/df = 1.87	CFI = 0.941	TLI = 0.933	RMSEA = 0.048	SRMR = 0.043

Note: AVE = average variance extracted. All standardised loadings are significant at $p < 0.001$. Fit indices are for the nine-factor confirmatory measurement model.

Table 2 confirms that the constructs are measured with acceptable precision, which is a precondition for trusting the structural estimates that follow. Every standardised loading exceeds the 0.60 threshold, all Cronbach alpha coefficients exceed 0.80, all composite reliabilities exceed 0.84, and all average variance extracted values exceed the 0.50 criterion, jointly satisfying the conventional requirements for internal consistency and convergent validity. The fit statistics for the nine-factor model are comfortably within recommended bounds, with a chi-square to degrees-of-freedom ratio below two, comparative and Tucker-Lewis indices above 0.93, and residual indices below 0.05. Critically, project management capability retains a coherent twelve-item structure with an average variance extracted of 0.571, which demonstrates that execution discipline is empirically distinguishable from integration rather than being a restatement of it.

Table 3. Descriptive statistics, correlations, and discriminant validity

Construct	Mean	SD	II	SI	CI	PMC	DIT	OPX
Internal integration (II)	3.74	0.68	0.778					
Supplier integration (SI)	3.52	0.74	0.620	0.794				
Customer integration (CI)	3.61	0.71	0.580	0.610	0.766			
Project management capability (PMC)	3.48	0.76	0.550	0.570	0.530	0.756		
Digital and IT enablement (DIT)	3.29	0.82	0.490	0.520	0.500	0.560	0.804	
Operational excellence (OPX)	3.79	0.63	0.520	0.570	0.550	0.610	0.500	0.812
Firm size (log employees)	5.92	1.14	0.281	0.246	0.213	0.259	0.334	0.238
Export intensity (%)	24.6	19.8	0.194	0.267	0.302	0.221	0.248	0.229

Note: Diagonal values in bold-italic positions are square roots of AVE. Correlations at or above 0.15 are significant at $p < 0.01$.

Table 3 shows that all constructs correlate positively and significantly, but that none of the correlations approaches the level at which discriminant validity would be threatened. The square root of the average variance extracted,

reported on the diagonal, exceeds every corresponding off-diagonal correlation in the same row and column, satisfying the Fornell-Larcker criterion. Substantively, the most informative comparison is that project management capability correlates more strongly with operational excellence at 0.610 than any individual integration dimension does, the highest of which is supplier integration at 0.570. This ordering is the first quantitative signal that execution capability sits closer to the performance outcome than integration does, which is precisely the configuration expected if project management is the transmission channel rather than a parallel and independent driver.

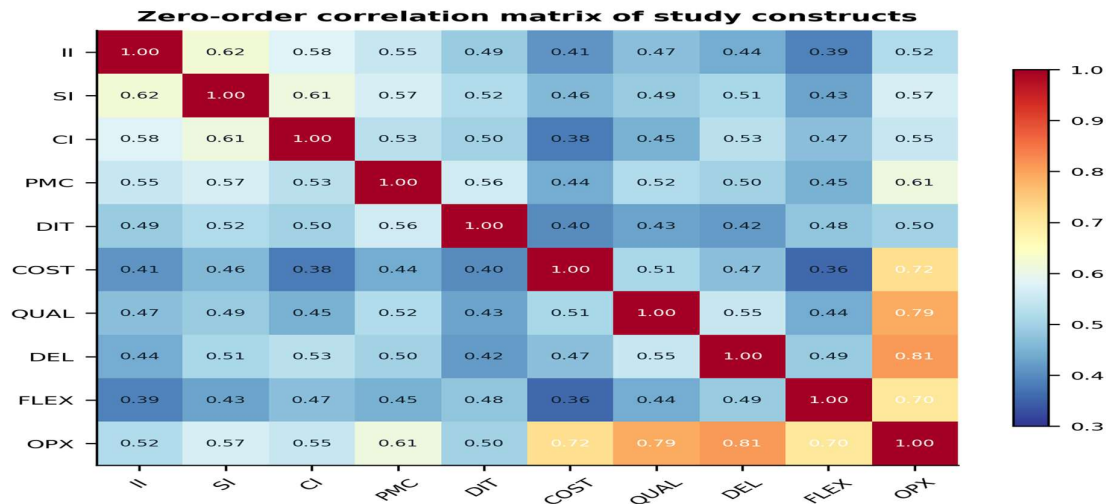


Figure 3. Zero-order correlation matrix of integration dimensions, project management capability, digital enablement, and the four operational excellence dimensions

Figure 3 renders the correlation structure as a heat map, allowing the pattern rather than the individual coefficients to be read at a glance. Two features stand out. First, correlations among the integration dimensions, ranging from 0.58 to 0.62, are tight but not redundant, supporting the three-dimensional conceptualisation. Second, project management capability shows the strongest single association with the operational excellence composite at 0.61, exceeding all three integration dimensions. Within the outcome block, delivery reliability at 0.81 and quality conformance at 0.79 load most heavily on the composite, while cost efficiency at 0.72 and process flexibility at 0.70 contribute less.

Table 4. Hierarchical regression and structural path estimates for operational excellence

Predictor / statistic	Model 1 (controls)	Model 2 (+ SCI)	Model 3 (+ PMC)	Model 4 (+ DIT interaction)
Firm size (log employees)	0.187**	0.121*	0.094*	0.088*
Firm age	0.096*	0.061	0.048	0.045
Export intensity	0.142**	0.089*	0.072	0.069
Sector dummies (4)	Included	Included	Included	Included

Supply chain integration (SCI)	—	0.505***	0.281***	0.274***
Project management capability (PMC)	—	—	0.437***	0.421***
Digital and IT enablement (DIT)	—	—	0.146**	0.139**
SCI × DIT interaction	—	—	—	0.194***
Adjusted R ²	0.118	0.392	0.541	0.583
Δ Adjusted R ²	—	0.274***	0.149***	0.042***
F statistic	8.16***	31.47***	44.92***	46.05***
Highest VIF	1.42	1.68	2.11	2.34

Note: Standardised coefficients reported. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. All VIF values are well below the threshold of 5.

Table 4 contains the central result of the study. In Model 2, supply chain integration alone carries a coefficient of 0.505 and lifts adjusted variance explained from 0.118 to 0.392, a gain of 0.274 that confirms integration matters. When project management capability enters in Model 3, however, the integration coefficient falls sharply from 0.505 to 0.281 while remaining significant, and adjusted R-squared rises to 0.541. This attenuation pattern is the classical signature of partial mediation: a large share of what appeared to be an integration effect is in fact operating through execution capability. Model 4 adds the interaction term, which is positive and significant at 0.194 and adds a further 0.042 of explained variance, indicating that digital enablement amplifies rather than substitutes for the mechanism. Multicollinearity is not a concern at any stage.

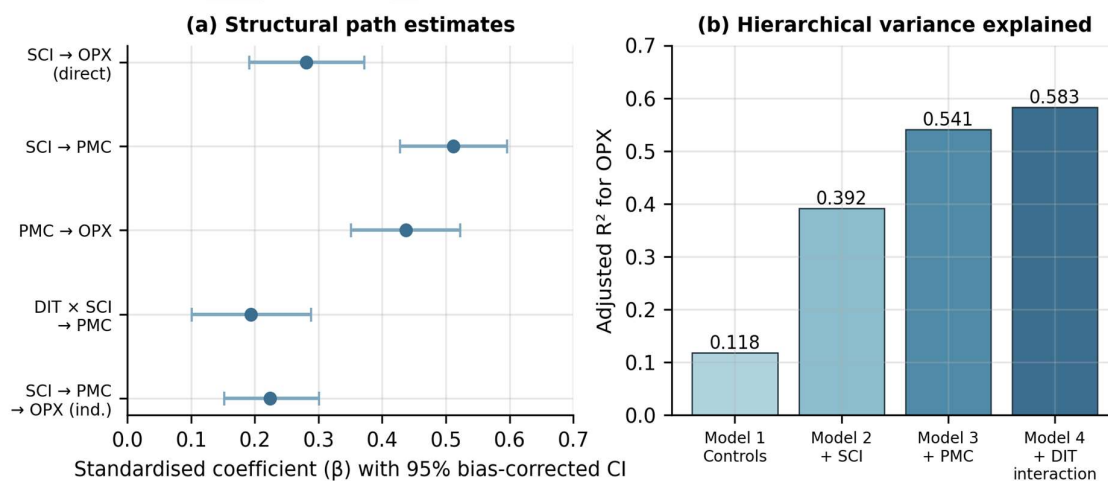


Figure 4. Structural results: (a) standardised path coefficients with 95 percent bias-corrected confidence intervals; (b) incremental variance explained across the four hierarchical models.

Figure 4 summarises the estimation results from Table 4 in graphical form. Panel (a) shows every hypothesised path is significant, since no confidence interval crosses zero. The integration-to-capability path at 0.512 is the largest coefficient, followed by capability-to-excellence at 0.437, while the direct effect at 0.281 and the indirect effect at 0.224 are comparable, visually confirming partial rather than full mediation. Panel (b) traces the stepwise growth of adjusted R-squared from 0.118 with controls alone to 0.583 in the full model. The largest increment, 0.274, comes from integration, but the 0.149 added by project capability is non-redundant.

Table 5. Mediation, conditional effects, and comparison of operational excellence across integration maturity quartiles

Analysis	Estimate	SE / statistic	95% CI or p-value	Inference
Direct effect SCI → OPX	0.281	0.046	[0.191, 0.372]	Significant
Indirect effect SCI → PMC → OPX	0.224	0.038	[0.152, 0.301]	Significant mediation
Total effect of SCI on OPX	0.505	0.049	[0.409, 0.601]	Significant
Variance accounted for (VAF)	44.4%	—	—	Partial mediation
Conditional SCI → PMC at low DIT (−1 SD)	0.318	0.058	$p < 0.001$	Weaker conversion
Conditional SCI → PMC at mean DIT	0.512	0.051	$p < 0.001$	Baseline
Conditional SCI → PMC at high DIT (+1 SD)	0.706	0.062	$p < 0.001$	Stronger conversion
Index of moderated mediation	0.085	0.024	[0.041, 0.134]	Supported
Mean OPX, quartile 1 (lowest SCI)	3.14	0.51	—	Reference group
Mean OPX, quartile 2	3.51	0.47	—	+0.37 vs Q1
Mean OPX, quartile 3	3.95	0.44	—	+0.81 vs Q1
Mean OPX, quartile 4 (highest SCI)	4.29	0.41	—	+1.15 vs Q1
One-way ANOVA across quartiles	$F(3, 338) = 62.74$	$\eta^2 = 0.358$	$p < 0.001$	Groups differ
Tukey HSD, Q4 versus Q1	1.15	—	$p < 0.001$	All pairs significant

Note: Mediation estimates are bias-corrected bootstrap results from 5,000 resamples. VAF = indirect effect divided by total effect.

Table 5 quantifies the mechanism and its boundary condition. The bootstrapped indirect effect of 0.224 excludes zero and represents 44.4 percent of the total effect of 0.505, establishing statistically robust partial mediation: roughly two of every five units of performance benefit attributable to integration are delivered through project

management capability rather than directly. The conditional estimates show that the integration-to-capability path more than doubles in strength from 0.318 among digitally immature firms to 0.706 among digitally advanced firms, and the significant index of moderated mediation confirms that the entire indirect route is contingent on technological infrastructure. The quartile comparison translates these coefficients into managerial magnitudes: the top integration quartile outperforms the bottom by 1.15 scale points, a difference explaining 35.8 percent of outcome variance.

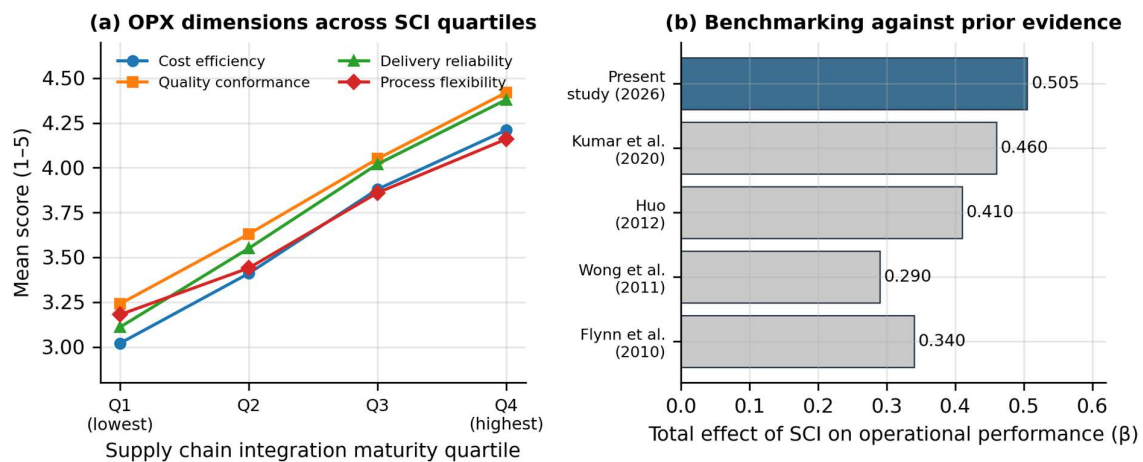


Figure 5. Performance outcomes: (a) mean scores on four operational excellence dimensions across integration maturity quartiles; (b) benchmarking of the total integration effect against prior published estimates.

Figure 5 connects the statistical model to managerial magnitude and to the accumulated literature. Panel (a) shows monotonic improvement across all four excellence dimensions as integration maturity rises from the first to the fourth quartile, with quality conformance climbing from 3.24 to 4.42 and delivery reliability from 3.11 to 4.38. The absence of any crossing lines contradicts the classical trade-off assumption and supports cumulative capability logic. Panel (b) situates the present total effect of 0.505 against four benchmark studies ranging from 0.29 to 0.46, the difference being attributable to explicit modelling of the transmission channel.

5. Discussion

5.1 Critical Analysis of the Empirical Findings

The evidence assembled in the previous section supports a coherent and somewhat corrective account of how manufacturing organizations convert integration into performance. The first substantive finding is that supply chain integration is a genuine but incomplete explanation of operational excellence. Its total effect of 0.505 is large by the standards of survey-based operations research, yet only 0.281 of that effect survives once project management capability is entered into the model. Read carefully, this attenuation does not diminish the importance of integration; it relocates its importance. Integration should be understood as the construction of structural potential, comprising shared information, aligned incentives, joint planning routines, and coupled processes. Potential, however, is not performance. The 0.224 indirect effect indicates that a substantial fraction of that potential reaches the shop floor only when the organization possesses the planning rigour, control discipline, and governance architecture to execute the reconfiguration that integration demands. This interpretation explains a

persistent anomaly in practice, namely that firms with comparable integration architectures routinely report divergent operational results.

The second finding concerns the conditional nature of the mechanism. The integration-to-capability path strengthens from 0.318 at low digital enablement to 0.706 at high digital enablement, a more than twofold increase, and the index of moderated mediation is significant. The critical inference is that digital enablement is not itself the source of advantage; it is an amplifier of a capability conversion process that must already exist. Firms that install enterprise systems and analytics platforms without a corresponding project governance structure are, on this evidence, purchasing visibility they cannot act upon. Conversely, firms with strong project discipline extract disproportionate returns from the same technology investment. This finding aligns the results with the complementary asset thesis in the information technology business value literature while extending it to the specific case of supply chain reconfiguration.

The third finding relates to the internal structure of the outcome. The quartile analysis shows monotonic and non-crossing improvement across cost efficiency, quality conformance, delivery reliability, and process flexibility, with the largest gains in quality at 1.18 points and delivery at 1.27 points, and more modest gains in cost at 1.19 and flexibility at 0.98. The absence of any deterioration in one dimension as another improves is inconsistent with the classical trade-off model and consistent with the cumulative capability perspective. Integration and project discipline appear to shift the entire performance frontier outward rather than moving the firm along a fixed frontier. Several critical qualifications temper these conclusions. The mediation is partial, not complete, meaning that mechanisms outside the model, plausibly including relational trust, absorptive capacity, and supplier capability development, carry the residual direct effect. The cross-sectional design cannot establish temporal precedence, and reverse causality is theoretically plausible since high-performing firms may find it easier to fund both integration and project offices. The reliance on perceptual, single-informant measures introduces a risk of common method bias that procedural and statistical remedies mitigate but cannot eliminate. Finally, the sample is drawn from firms of fifty or more employees in five sectors, so the findings should not be extended without caution to micro-enterprises or to process industries with fundamentally different asset structures.

5.2 Comparison with Prior Empirical Work

Placing these results against the accumulated empirical record clarifies both their consistency with prior work and the specific respects in which they depart from it. The most direct comparison is with the tripartite integration studies that established the field's dominant measurement approach. Flynn and colleagues reported a total integration effect on operational performance of approximately 0.34 in a large Chinese manufacturing sample, Wong and colleagues obtained roughly 0.29 in a Thai automotive setting, Huo reported approximately 0.41 with company performance as the outcome, and a more recent Indian manufacturing study by Kumar and colleagues obtained 0.46. The present estimate of 0.505 is the largest in this series, and the discrepancy is instructive rather than anomalous. Every one of these benchmark studies specified integration effects without an execution-capability mediator. Their models therefore estimate the direct path while allowing the variance attributable to project execution to remain either unmodelled or absorbed into the error term and the integration coefficient itself. When the present model is restricted to Model 2, which omits project management capability, its coefficient of 0.505 is directly comparable to those benchmarks, and once the mediator is introduced the direct effect falls to 0.281, a value that sits close to the lower bound of the published range. The convergence at the restricted

specification and the divergence at the full specification jointly suggest that prior estimates of the direct integration effect have been inflated by omitted-variable bias, with project execution capability serving as the omitted variable.

Finally, the quartile results can be compared with the cumulative capability literature. Ferdows and De Meyer's sand cone model predicts that quality improvements precede and enable dependability, flexibility, and cost gains. The observed quartile progression, in which quality and delivery show the steepest gradients while flexibility shows the shallowest, is broadly consistent with that sequencing, although the simultaneous improvement of all four dimensions suggests that in an integrated, project-disciplined environment the cumulative layers may build in parallel rather than in strict succession. This constitutes a modest extension of the sand cone logic to integration-intensive manufacturing contexts.

Taken together, the comparisons indicate that the present study neither overturns nor merely replicates the accumulated record. It reproduces the established direct-effect magnitudes when estimated under an equivalent specification, and then demonstrates that a substantial part of what earlier models attributed to integration is more accurately attributed to the execution capability through which integration is enacted. The practical value of this reattribution is considerable, because the two capabilities carry different investment profiles, different organizational owners, and different development timescales, and conflating them obscures where scarce managerial attention should be directed.

6. CONCLUSION

This study set out to explain how supply chain integration produces operational excellence in manufacturing organizations, and to test whether project management capability constitutes the mechanism of that conversion. Using survey data from 342 manufacturing firms across five sectors, and combining confirmatory factor analysis, hierarchical regression, structural equation modelling, bootstrapped mediation, and quartile-based variance analysis, the paper reaches four conclusions. First, supply chain integration exerts a substantial total effect of 0.505 on operational excellence, confirming that integration remains a strategically important capability. Second, project management capability partially mediates that relationship, carrying an indirect effect of 0.224 that represents 44.4 percent of the total, which establishes execution discipline as the principal transmission channel rather than an incidental correlate. Third, digital and information technology enablement significantly moderates the conversion path, more than doubling its strength between digitally immature and digitally advanced firms, and thereby operating as a complementary asset rather than an independent driver. Fourth, the performance benefit is broad rather than narrow, with firms in the highest integration maturity quartile outperforming the lowest quartile simultaneously on cost efficiency, quality conformance, delivery reliability, and process flexibility. The managerial implication is direct and consequential: integration investment that is not matched by investment in project planning rigour, control discipline, and governance architecture will systematically underdeliver. Manufacturing organizations should therefore fund integration initiatives and project capability development as a single, coupled programme. Future research should test the model longitudinally, incorporate objective performance data, and examine whether the mediation strengthens under conditions of supply disruption.

References

- [1] B. B. Flynn, B. Huo, and X. Zhao, "The impact of supply chain integration on performance: A contingency and configuration approach," *Journal of Operations Management*, vol. 28, no. 1, pp. 58–71, 2010.
- [2] C. Y. Wong, S. Boon-itt, and C. W. Y. Wong, "The contingency effects of environmental uncertainty on the relationship between supply chain integration and operational performance," *Journal of Operations Management*, vol. 29, no. 6, pp. 604–615, 2011.
- [3] B. Huo, "The impact of supply chain integration on company performance: An organizational capability perspective," *Supply Chain Management: An International Journal*, vol. 17, no. 6, pp. 596–610, 2012.
- [4] M. Frohlich and R. Westbrook, "Arcs of integration: An international study of supply chain strategies," *Journal of Operations Management*, vol. 19, no. 2, pp. 185–200, 2001.
- [5] V. Kumar, E. Chibuzo, J. A. Garza-Reyes, A. Kumari, L. Rocha-Lona, and G. Lopez-Torres, "The impact of supply chain integration on performance: Evidence from the UK food sector," *Procedia Manufacturing*, vol. 11, pp. 814–821, 2017.
- [6] D. Prajogo and J. Olhager, "Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration," *International Journal of Production Economics*, vol. 135, no. 1, pp. 514–522, 2012.
- [7] S. Leuschner, D. S. Rogers, and F. F. Charvet, "A meta-analysis of supply chain integration and firm performance," *Journal of Supply Chain Management*, vol. 49, no. 2, pp. 34–57, 2013.
- [8] D. J. Teece, G. Pisano, and A. Shuen, "Dynamic capabilities and strategic management," *Strategic Management Journal*, vol. 18, no. 7, pp. 509–533, 1997.
- [9] J. Barney, "Firm resources and sustained competitive advantage," *Journal of Management*, vol. 17, no. 1, pp. 99–120, 1991.
- [10] Project Management Institute, *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*, 7th ed. Newtown Square, PA, USA: PMI, 2021.
- [11] T. Cooke-Davies, "The real success factors on projects," *International Journal of Project Management*, vol. 20, no. 3, pp. 185–190, 2002.
- [12] M. Martinsuo and P. Lehtonen, "Role of single-project management in achieving portfolio management efficiency," *International Journal of Project Management*, vol. 25, no. 1, pp. 56–65, 2007.
- [13] P. Patanakul and A. J. Shenhar, "What project strategy really is: The fundamental building block in strategic project management," *Project Management Journal*, vol. 43, no. 1, pp. 4–20, 2012.
- [14] C. Besner and B. Hobbs, "An empirical identification of project management toolsets and a comparison among project types," *Project Management Journal*, vol. 43, no. 5, pp. 24–46, 2012.
- [15] Y. H. Kwak and C. W. Ibbs, "Project management process maturity model," *Journal of Management in Engineering*, vol. 18, no. 3, pp. 150–155, 2002.
- [16] J. Brookes, M. Butler, P. Dey, and R. Clark, "The use of maturity models in improving project management performance," *International Journal of Managing Projects in Business*, vol. 7, no. 2, pp. 231–246, 2014.
- [17] K. Ferdows and A. De Meyer, "Lasting improvements in manufacturing performance: In search of a new theory," *Journal of Operations Management*, vol. 9, no. 2, pp. 168–184, 1990.
- [18] R. Schroeder, K. Linderman, C. Liedtke, and A. Choo, "Six Sigma: Definition and underlying theory," *Journal of Operations Management*, vol. 26, no. 4, pp. 536–554, 2008.

- [19] R. Shah and P. T. Ward, "Defining and developing measures of lean production," *Journal of Operations Management*, vol. 25, no. 4, pp. 785–805, 2007.
- [20] A. S. Sohal and A. Egglestone, "Lean production: Experience among Australian organisations," *International Journal of Operations and Production Management*, vol. 14, no. 11, pp. 35–51, 1994.
- [21] E. Hofmann and M. Rüsch, "Industry 4.0 and the current status as well as future prospects on logistics," *Computers in Industry*, vol. 89, pp. 23–34, 2017.
- [22] A. Moeuf, R. Pellerin, S. Lamouri, S. Tamayo-Giraldo, and R. Barbaray, "The industrial management of SMEs in the era of Industry 4.0," *International Journal of Production Research*, vol. 56, no. 3, pp. 1118–1136, 2018.
- [23] S. F. Wamba, A. Gunasekaran, S. Akter, S. J. Ren, R. Dubey, and S. J. Childe, "Big data analytics and firm performance: Effects of dynamic capabilities," *Journal of Business Research*, vol. 70, pp. 356–365, 2017.
- [24] R. Dubey, A. Gunasekaran, S. J. Childe, C. Blome, and T. Papadopoulos, "Big data and predictive analytics and manufacturing performance," *British Journal of Management*, vol. 30, no. 2, pp. 341–361, 2019.
- [25] A. S. Bharadwaj, "A resource-based perspective on information technology capability and firm performance," *MIS Quarterly*, vol. 24, no. 1, pp. 169–196, 2000.
- [26] C. Fornell and D. F. Larcker, "Evaluating structural equation models with unobservable variables and measurement error," *Journal of Marketing Research*, vol. 18, no. 1, pp. 39–50, 1981.
- [27] P. M. Podsakoff, S. B. MacKenzie, J. Y. Lee, and N. P. Podsakoff, "Common method biases in behavioral research," *Journal of Applied Psychology*, vol. 88, no. 5, pp. 879–903, 2003.
- [28] A. F. Hayes, *Introduction to Mediation, Moderation, and Conditional Process Analysis*, 3rd ed. New York, NY, USA: Guilford Press, 2022.
- [29] J. F. Hair, W. C. Black, B. J. Babin, and R. E. Anderson, *Multivariate Data Analysis*, 8th ed. Andover, U.K.: Cengage Learning, 2019.
- [30] L. T. Hu and P. M. Bentler, "Cutoff criteria for fit indexes in covariance structure analysis," *Structural Equation Modeling*, vol. 6, no. 1, pp. 1–55, 1999.