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From IT Capability to Manufacturing Flexibility: The Role of Knowledge Acquisition and Customer–Supplier Integration

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Abstract

Background: This study examines how information technology (IT) capability contributes to manufacturing flexibility (MF) through knowledge acquisition (KA) and customer–supplier integration (CSI), drawing on dynamic capability theory. *Methods*: Survey data were collected from 137 manufacturing firms in Thailand and analyzed using structural equation modeling to test the proposed relationships. *Results*: The findings show that IT capability significantly enhances KA, which subsequently strengthens CSI. While IT does not directly influence MF, its effect is transmitted through a sequential pathway in which IT improves KA, KA facilitates CSI, and CSI is the only construct directly associated with MF. These results identify CSI as the central conversion mechanism through which IT-enabled information and externally acquired knowledge are translated into operational adaptability. *Conclusions*: The study demonstrates that externally acquired knowledge generates value only when embedded in collaborative interorganizational routines, such as joint planning and synchronized decision-making. It further highlights the complementary roles of learning-oriented and integration capabilities in enabling manufacturing flexibility. Managerially, firms should prioritize IT investments that strengthen customer–supplier integration rather than focusing solely on technological sophistication.

Keywords: manufacturing flexibility; information technology capability; knowledge acquisition; customer–supplier integration; dynamic capabilities; supply chain integration

1. Introduction

Manufacturing flexibility (MF) has become a critical competitive capability for firms operating in increasingly volatile and interconnected supply chains. Intensified global competition, rapid technological change, and frequent supply disruptions have heightened the need for manufacturers to respond quickly and efficiently to changing market [1–3]. Consequently, MF is widely regarded as a key source of operational resilience and sustainable competitive advantage, enabling firms to adjust production volume, mix, and processes in response to market uncertainty.

Information technology (IT) has long been recognized as an important enabler of organizational and operational capabilities [4]. Prior studies suggest that IT enhances information visibility, coordination, and decision-making both within firms and across organizational boundaries [5–7]. In supply chain contexts, IT supports real-time information exchange among customers and suppliers, thereby facilitating more responsive operations. However, empirical evidence regarding the direct impact of IT on MF remains inconclusive. While some studies report positive relationships, others argue that IT alone is insufficient to improve operational outcomes without complementary organizational and

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interorganizational capabilities [4,8,9]. These mixed findings indicate the need to examine the underlying mechanisms through which IT contributes to MF.

One potential mechanism is knowledge acquisition (KA), defined as a firm's capability to identify, access, and absorb knowledge from external sources [10]. In supply chain environments, IT primarily facilitates externally oriented learning by enabling firms to obtain knowledge from customers and suppliers, such as information related to demand changes, new technologies, and process improvements [11]. KA therefore represents a critical sensing capability that allows firms to detect environmental changes and update their internal knowledge base [12]. Through this process, firms are better positioned to recognize emerging opportunities and threats in dynamic markets.

Nevertheless, acquiring external knowledge alone may not be sufficient to enhance MF. For knowledge to generate operational value, it must be embedded into collaborative routines and coordinated decision-making across the supply chain. Customer–supplier integration (CSI) plays a crucial role in this transformation by enabling joint planning, information sharing, and synchronized operations with both upstream suppliers and downstream customers [13,14]. Through CSI, firms can translate externally acquired knowledge into aligned production plans, improved responsiveness, and superior operational performance [15].

Despite the recognized importance of IT, KA, and CSI, prior research has rarely examined their combined roles from a process perspective. Many studies treat integration as a single-stage outcome or assume direct relationships between knowledge-related capabilities and MF, overlooking the possibility that IT is associated with flexibility through a staged capability-building process. This limitation leaves the mechanism linking technological resources to operational outcomes largely unexplored. Unlike prior studies that focus on direct or parallel relationships, this study develops a sequential capability framework that offers an explanatory mechanism for the observed associations between IT capability and MF.

Drawing on the dynamic capability perspective [16,17], this study conceptualizes capability development as a sequential transformation process. IT-enabled KA represents the sensing mechanism through which firms capture external signals, while CSI reflects the seizing and reconfiguring capability that allows firms to realign supply chain relationships and operational processes. Accordingly, this study proposes that IT contributes to MF indirectly by first enabling KA, which subsequently facilitates CSI.

This study contributes to the literature in three ways. First, it develops a process-based explanation of how IT supports MF by theorizing and CSI as sequential capabilities. Second, it reconceptualizes KA as an enabling capability whose value depends on interorganizational integration rather than as a direct driver of operational outcomes. Third, it provides managerial implications by emphasizing that investments in IT and learning capabilities should be complemented by strong CSI practices to achieve meaningful improvements in MF.

2. Theoretical Background and Hypotheses Development

2.1. Dynamic Capabilities Theory

Dynamic capability theory explains how firms build, integrate, and reconfigure resources and capabilities to respond to rapidly changing environments [17]. Unlike static perspectives that focus on resource possession, dynamic capability theory emphasizes processes and mechanisms through which firms transform resources into competitive advantage. According to this perspective, organizational performance outcomes do not arise directly from individual resources or technologies. Instead, performance is achieved

through a sequence of higher-order capabilities that enable firms to sense environmental changes, seize opportunities, and reconfigure operational processes [16].

This theoretical logic suggests that technological resources such as IT do not automatically generate operational outcomes. Rather, their value depends on complementary organizational and interorganizational capabilities that translate technological potential into action.

Building on this perspective, dynamic capabilities can be understood through the sensing–seizing–reconfiguring framework. These capabilities are interrelated and sequential, such that sensing enables seizing, and seizing enables reconfiguring. Accordingly, value creation arises through a staged capability development process rather than from isolated resources.

2.2. Dynamic Capabilities as a Sequential Process

A key contribution of dynamic capability theory is its emphasis on capability sequencing. Teece [16] conceptualizes dynamic capabilities as comprising three interrelated activities: (1) Sensing opportunities and threats (2) Seizing opportunities through organizational and strategic commitments (3) Reconfiguring assets and routines to maintain alignment with environmental demands.

Importantly, these activities are interdependent and sequential, meaning that later-stage capabilities build upon earlier ones. Specifically, sensing capabilities enable firms to identify and acquire relevant external knowledge, which must then be mobilized through seizing and reconfiguring activities to generate operational outcomes. This implies that capabilities operate through a staged transformation process rather than independently.

Failure at any stage can prevent firms from realizing performance benefits, even if earlier capabilities are present. This sequential logic provides a strong theoretical foundation for examining mediated and serial relationships, rather than direct relationships, between organizational capabilities and performance outcomes.

2.3. Information Technology and Knowledge Acquisition

Information technology (IT) plays a critical role in enabling firms to acquire knowledge from external sources by enhancing information accessibility, connectivity, and processing capabilities.

From a dynamic capability perspective, IT capability can be explicitly positioned as an enabler of sensing, as it enhances information visibility and connectivity, allowing firms to identify and access valuable external knowledge from customers, suppliers, and other partners [4,16]. IT capability is conceptualized in this study as an enabling infrastructure capability rather than mere technology adoption. The selected indicators (e.g., ERP, MRP, and e-business systems) reflect the firm's ability to deploy and integrate digital technologies to enhance information visibility and coordination across the supply chain. In this sense, IT capability supports sensing by facilitating access to external information and enabling KA processes [4,16].

Prior research suggests that IT enhances KA by expanding firms' access to diverse external knowledge sources and reducing information asymmetries within supply chains [11]. IT capability facilitates knowledge processes, which include KA [18]. Through tools such as enterprise systems, interorganizational platforms, and data-sharing technologies, firms are better able to collect, monitor, and interpret information related to customer demand, supplier capabilities, and technological developments. These IT-enabled mechanisms strengthen firms' capacity to identify and acquire relevant knowledge beyond their organizational boundaries.

These theoretical and empirical insights suggest that IT is associated with KA by enabling firms to sense, access, and absorb external knowledge from customers and suppliers. Accordingly, this study proposes the following hypothesis:

H1: *Information technology is positively associated with knowledge acquisition.*

2.4. Knowledge Acquisition and Customer–Supplier Integration

Knowledge acquisition (KA) refers to a firm's capability to identify, access, and absorb knowledge from external sources such as suppliers, customers, and other supply chain partners [10].

In dynamic and competitive environments, externally acquired knowledge provides firms with valuable insights into market trends, customer requirements, and partner capabilities. However, the acquisition of knowledge alone does not automatically improve operational outcomes unless it is embedded into interorganizational processes and collaborative routines.

From a dynamic capability perspective, KA represents a sensing capability that enables firms to recognize changes and opportunities in their external environment [16]. This sensing role is rooted in microfoundations of environmental scanning and assimilation of external knowledge, consistent with absorptive capacity theory, which emphasizes a firm's ability to identify and absorb valuable external information. Dynamic capability theory suggests that sensing capabilities must be complemented by higher-order capabilities that allow firms to seize opportunities and reconfigure organizational and interorganizational processes. In supply chain contexts, this is realized through seizing–reconfiguring capabilities embodied in CSI, which involves joint planning, information sharing, and coordinated decision-making with upstream and downstream partners [13].

Customer–supplier integration (CSI) provides the structural and relational mechanisms through which externally acquired knowledge can be shared, interpreted, and applied across organizational boundaries. Firms that actively acquire knowledge from suppliers and customers are likely to better appreciate the benefits of closer collaboration [11], as knowledge about partner capabilities, demand patterns, and operational constraints can highlight opportunities for coordination and joint problem-solving. Empirical and conceptual studies indicate a positive association between KA and customer–supplier integration. Early empirical evidence shows that firms with stronger KA and dissemination activities tend to develop integrative supply chain practices (e.g., customer–supplier) that support coordination and performance [19].

Research grounded in dynamic capability perspectives further suggests that externally acquired knowledge enhances firms' ability to identify collaboration opportunities and update interorganizational processes, which are foundational to CSI [12]. These studies together suggest that KA can serve as a critical antecedent to CSI by improving firms' ability to recognize the value of collaboration, align processes, and coordinate activities across supply chain boundaries. These findings suggest that KA serves as a critical antecedent to customer–supplier integration by enabling firms to identify collaboration opportunities and align interorganizational processes.

Taken together, these theoretical and empirical insights indicate that firms that actively acquire knowledge from external partners are better positioned to develop and sustain customer–supplier integration. By enhancing awareness of partner needs and environmental changes, KA motivates and enables firms to engage in closer collaboration across the supply chain. Accordingly, this study proposes the following hypothesis:

H2: *Knowledge acquisition is positively associated with customer–supplier integration.*

2.5. Customer–Supplier Integration and Manufacturing Flexibility

Manufacturing flexibility (MF) refers to a firm's ability to effectively adjust production volumes, product mix, and processes in response to changes in market demand and environmental uncertainty [1,20]. In increasingly dynamic and interconnected supply chain environments, achieving MF requires not only strong internal operational capabilities but also seamless coordination with external supply chain partners. As a result, supply chain integration—especially integration with both suppliers and customers—has been identified as a critical antecedent of MF and overall supply chain performance [21].

Customer–supplier integration involves the extent to which firms engage in collaborative planning, information sharing, and coordinated decision-making with upstream suppliers and downstream customers [13]. Through such integration, firms gain access to timely and accurate information regarding customer demand, supplier capabilities, and potential supply disruptions. This shared information enables firms to anticipate changes and respond more effectively through flexible manufacturing adjustments [21].

From a dynamic capability perspective, CSI can be conceptualized as a seizing–reconfiguring capability, as it involves initial commitments to collaborate (seizing) followed by the continuous alignment of interorganizational routines (reconfiguring). Through this capability deployment, MF can be understood as the operational outcome that emerges when firms effectively align and reconfigure resources and processes across supply chain partners.

Dynamic capability theory suggests that operational outcomes such as MF emerge when firms are able to reconfigure resources and routines across organizational boundaries. CSI facilitates this reconfiguration by embedding collaborative routines that support rapid coordination and joint problem-solving across the supply chain.

Empirical studies provide strong support for the positive relationship between CSI and MF. Flynn, Huo and Zhao [13] demonstrate that firms with higher levels of CSI exhibit superior operational performance, including responsiveness and flexibility. Similarly, Wong, Boon-Itt and Wong [14] find that closer integration with supply chain partners enhances firms' ability to cope with environmental uncertainty by improving coordination and adaptability. These findings suggest that integration strengthens a firm's capacity to adjust production plans and manufacturing processes in response to changing conditions.

Moreover, CSI enhances MF by enabling synchronized decision-making across the supply chain. Through joint forecasting, collaborative planning, and shared production schedules, firms can reduce information delays and misalignment, allowing faster and more effective manufacturing [22]. Integration also supports flexibility by improving mutual understanding of constraints and capabilities among supply chain partners, thereby facilitating coordinated responses to demand variability and supply disruptions.

Taken together, these theoretical and empirical insights indicate that customer–supplier integration plays a critical role in enhancing MF. By fostering close collaboration and coordinated action with both suppliers and customers, firms are better able to translate shared information and joint knowledge into adaptive manufacturing responses. Accordingly, this study proposes the following hypothesis:

H3: *Customer–Supplier integration is positively associated with manufacturing flexibility.*

2.6. The Conceptual Model

Figure 1 summarizes the conceptual model linking IT, KA, customer–supplier integration, and MF. Grounded in dynamic capability theory [16], the framework maps study constructs onto the sensing–seizing–reconfiguring logic of dynamic capability theory. IT is conceptualized as an enabler of sensing, as it expands access to external information. KA

represents the sensing stage, while CSI reflects seizing–reconfiguring capabilities involving both commitment to collaborate and alignment of interorganizational routines. MF is modeled as the operational outcome of this staged process. The proposed model adopts a sequential mediation structure consistent with the staged nature of capability development in dynamic capability theory.

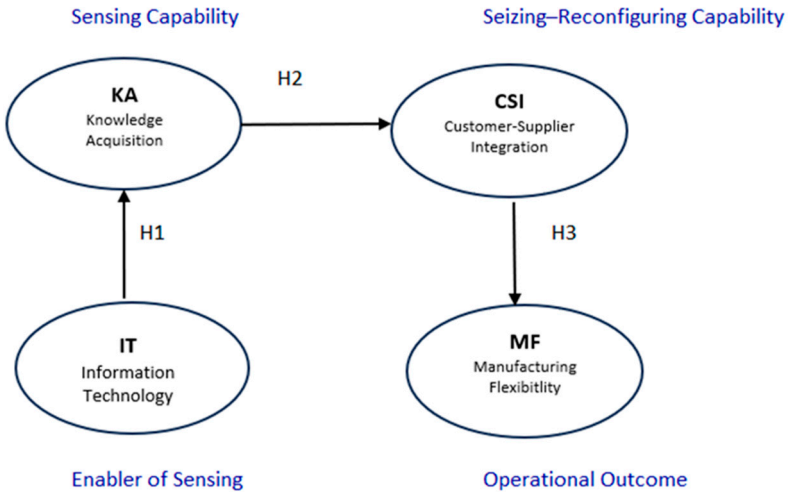


Figure 1. Conceptual model.

Taken together, the model reflects a sequential capability development process in which IT-enabled sensing supports KA, which in turn enables seizing and reconfiguring through CSI, ultimately leading to MF as the operational outcome.

3. Materials and Methods

3.1. Sampling and Data Collection

The target population consisted of manufacturing firms from three distinct industries: (1) automotive parts and supplies, (2) electronics parts and equipment, and (3) food manufacturing. These industries were selected because they are among the most significant contributors to Thailand's economy in terms of gross profit and export value and have been leaders in adopting supply chain management practices. Moreover, the inclusion of multiple industries enhances the external validity and generalizability of the findings.

Respondent selection was carefully considered to ensure the reliability of the data. Respondents were required to have sufficient knowledge of supply chain integration practices, KA activities, and firm operational capabilities. The unit of analysis was the firm at the corporate level, consistent with prior operations management research [23]. The independent variables; IT, KA, CSI—reflect organizational-level practices, while MF represents a firm-level performance outcome.

The sampling frame was compiled from two sources: (1) the Factory Directory in Thailand (2011) and (2) the Factory List from the Office of Industrial Estate. The target respondents included purchasing and materials managers as well as senior executives such as CEOs, presidents, vice presidents, and directors. The initial mailing list consisted of 700 firms. Prior to distributing the questionnaires, mailing addresses were screened to ensure valid postal codes. To improve the response rate, potential respondents were contacted by telephone to explain the purpose of the study and invite participation. Questionnaires were mailed together with a cover letter outlining the objectives and contributions of the research.

A total of 137 complete and usable questionnaires were returned, resulting in a response rate of 19.6%, which is comparable to those reported in previous supply chain

management studies [24]. The sample size exceeds the recommended threshold for SEM analyses [25] and is comparable to prior supply chain management survey studies, supporting the adequacy of the data for structural model estimation. The majority of respondents occupied middle- to senior-level positions in logistics, supply chain management, or plant management. Firms from all three industries were represented, and the sample included a diverse range of firm sizes and ownership structures. Firm size was included as a control variable because prior research suggests that larger firms may possess greater resources, more advanced IT infrastructure, and stronger integration capabilities, which could influence the relationships among the focal constructs. Firm size was measured based on the number of employees and modeled as an exogenous control variable in the structural model.

Several procedural remedies were applied to minimize common method bias, including respondent anonymity and careful item wording. In addition, a common latent factor approach was employed as a statistical diagnostic.

3.2. Measurement Instrument Development and Measurement Scales

To develop and validate the survey instrument, a comprehensive review of prior studies was conducted to identify established measurement scales for each construct. Before the main data collection, the initial set of items was pre-tested with both academic experts and industry practitioners to ensure clarity and appropriateness. Subsequently, scale refinement was carried out through a pilot study using expert judgment and the Q-sort procedure to preliminarily assess construct validity and reliability. A panel consisting of five academic researchers and ten practitioners with expertise relevant to the study constructs evaluated the questionnaire. Based on their feedback, which primarily concerned item wording, minor revisions were made to improve clarity and consistency. All items were measured using five-point Likert-type scales. For IT, KA, and CSI, the scale ranged from 1 = not used at all to 5 = used at the highest level. For MF, the scale ranged from 1 = strongly disagree to 5 = strongly agree.

IT in supply chain management was measured using items adapted from established scales developed by Auramo, et al. [26] and Bayraktar, et al. [27]. These items capture the extent to which firms utilize and integrate digital systems to support supply chain processes, thereby reflecting an operationalized form of IT capability.

KA was measured using items adapted from prior studies conducted in supply chain management contexts, including Massa and Testa [28], Fugate, et al. [29], Samuel, et al. [30]. In this study, KA is conceptualized as a sensing capability within the dynamic capability framework, emphasizing the identification and acquisition of knowledge from external supply chain partners. While some items capture internal learning processes, these are considered supportive mechanisms that enable effective sensing.

These items assess the extent to which a firm acquires and develops knowledge from multiple sources across functional departments and throughout the supply chain. Specifically, the measures capture a firm's ability to identify, obtain, and absorb external knowledge from customers and suppliers as well as internal knowledge from different functional areas. CSI was measured using scales adapted from Narasimhan and Kim [31], Rai, et al. [32] Flynn, Huo and Zhao [13], and Wong, Boon-Itt and Wong [14]. This construct captures the degree of collaboration and coordination between a firm and its upstream suppliers and downstream customers. Finally, MF was measured using items adapted from Rosenzweig, et al. [33], Boon-itt [34], and Wong, Boon-Itt and Wong [14]. This construct was assessed using four items that capture a firm's ability to efficiently reconfigure resources and adjust production processes to accommodate changes in product mix, volume, and

customer requirements. The questionnaire used in this study is provided in Supplementary Materials (Table S1).

3.3. Descriptive Statistics and Construct Correlations

Table 1 presents the characteristics of the sample firms. The majority of firms are medium to large in size, with nearly one-third employing 700 or more employees, indicating that the sample includes organizations with substantial operational scale. Respondents primarily occupy managerial positions related to supply chain, production, and general management, suggesting that they possess sufficient knowledge of firm-level operations and supply chain practices. In addition, most respondents have considerable work experience, with over 45% reporting more than 10 years of experience, which enhances the reliability and credibility of the survey responses.

Table 1. Characteristics of sample firms (n = 137).

Characteristics	Number	%
Number of employees		
≤50	9	6.6
51–100	23	16.8
101–200	27	19.7
201–350	17	12.4
351–700	17	12.4
≥700	42	30.7
Not available	2	1.4
Roles of respondents		
President, Vice President, Managing Director	8	5.8
General Manager	29	21.2
Plant Manager	15	10.9
Purchasing/Logistics/Distribution/Supply Chain Manager	25	18.2
Manufacturing/Production Manager	24	17.5
Others	36	26.3
Year of experiences		
<2 years	18	13.1
2–5 years	31	22.6
6–10 years	23	16.8
>10 years	62	45.3
Not available	3	2.2

Table 2 presents the descriptive statistics and Pearson correlation coefficients among the key study constructs. The mean values indicate moderate to relatively high levels. The correlation analysis shows that IT is positively and significantly associated with KA (r = 0.47, $p < 0.01$) and CSI (r = 0.42, $p < 0.01$). KA is also positively related to customer–supplier integration (r = 0.50, $p < 0.01$). In addition, MF is positively correlated with IT (r = 0.36, $p < 0.01$), KA (r = 0.29, $p < 0.01$), and customer–supplier integration (r = 0.43, $p < 0.01$).

Table 2. Descriptive Statistics & Construct Correlations.

Variables	Mean	S.D.	IT	KA	CSI
(1) Information Technology (IT)	3.09	1.04			
(2) Knowledge Acquisition (KA)	3.74	0.77	0.47 **		
(3) Customer- Supplier Integration (CSI)	3.31	0.83	0.42 **	0.50 **	
(4) Manufacturing Flexibility (MF)	3.42	0.81	0.36 **	0.29 **	0.43 **

Notes: n = 137; ** $p < 0.01$.

Overall, the significant positive correlations provide preliminary support for the hypothesized relationships among the constructs and suggest that higher levels of IT, KA, and customer–supplier integration are associated with greater MF. At the same time, the correlation coefficients remain below commonly accepted thresholds for multicollinearity, indicating that the constructs are empirically distinct and suitable for subsequent structural equation modeling.

4. Results

4.1. Analytical Procedures

The primary factors in our model are underlying concepts that are not directly observed, known as latent constructs. Therefore, we considered the Structural Equation Model (SEM) as an appropriate method. SEM allows for the modeling of latent variables, which are constructs that cannot be directly measured but are inferred from observed indicators. This approach is valuable when studying abstract concepts or constructs that are difficult to measure directly. We employed AMOS 28 as the software tool for conducting SEM estimations.

4.2. Measurement Model Assessment

The reliability and validity of the measurement model were assessed using confirmatory factor analysis (CFA). The measurement model demonstrated an acceptable fit to the data ($\chi^2/df = 1.64$, CFI = 0.945, TLI = 0.927, RMSEA = 0.069), indicating that the proposed measurement structure fits the data well.

Table 3 presented measurement items and factor loadings. All standardized factor loadings are statistically significant and exceed the minimum recommended threshold of 0.50 [25], ranging from 0.553 to 0.890, indicating acceptable indicator reliability [25]. Cronbach's alpha values range from 0.79 to 0.87, exceeding the recommended threshold of 0.70 and demonstrating satisfactory internal consistency reliability [35]. Although some factor loadings are relatively low to the 0.50 threshold, all items were retained as they meet the minimum acceptable level and contribute to content validity. Additional checks, including consideration of modification indices and item removal, did not result in meaningful improvements in model fit or reliability. Therefore, the original measurement model was retained.

Table 3. Measurement Model.

	Constructs and Items	Loadings	α
	Information Technology (IT)		0.83
1.	Use of E-business	0.553	
2.	Use of Enterprise Resources Planning (ERP)	0.787	
3.	Use of Material Requirement Planning (MRP)	0.871	
	Knowledge Acquisition (KA)		0.87
1.	Value employees' attitudes and opinions	0.711	
2.	Encourage employees to improve and upgrade their skills by continuously learning new things	0.890	
3.	Continuously monitor changes in marketplace or environment to obtain new knowledge	0.793	
	Customer–Supplier Integration (CSI)		0.83

Table 3. *Cont.*

	Constructs and Items	Loadings	α
1.	Share actual sales data and market information with customers	0.737	
2.	Joint planning and forecasting with major customers	0.715	
3.	Joint planning and forecasting with major suppliers	0.726	
4.	Involve suppliers in product design and development processes	0.583	
	Manufacturing Flexibility (MF)		0.79
1.	Able to change production volume (e.g., become mass production) in a short period	0.571	
2.	Produce broad product specifications within same facility	0.786	
3.	Capable of making rapid changes in product specification and becoming settled in short time	0.806	

Further evidence of construct reliability and convergent validity is provided in Table 4. Composite reliability (CR), which assesses internal consistency reliability, ranges from 0.79 to 0.87, exceeding the recommended threshold of 0.70 [25].

Table 4. Reliability & Validity.

Construct	CR	AVE	IT	KA	CSI	MF
(1) Information Technology (IT)	0.83	0.56	0.75			
(2) Knowledge Acquisition (KA)	0.87	0.69	0.54	0.83		
(3) Customer–Supplier Integration (CSI)	0.83	0.52	0.50	0.60	0.72	
(4) Manufacturing Flexibility (MF)	0.79	0.52	0.40	0.32	0.51	0.72

Note: Diagonal values represent the square root of AVE; AVE = Average variance extracted.

Convergent validity was evaluated using average variance extracted (AVE), with values ranging from 0.52 to 0.69, surpassing the recommended threshold of 0.50 [25]. These results indicate that the constructs adequately capture the variance of their indicators.

Discriminant validity was assessed using the Fornell–Larcker criterion, which requires that the square root of AVE for each construct be greater than its correlations with other constructs [25]. As shown in Table 4, this condition is satisfied, indicating satisfactory discriminant validity.

Overall, these results confirm that the measurement model demonstrates adequate reliability, convergent validity, and discriminant validity.

4.3. Common Method Bias (CMB)

To assess potential common method bias, both procedural and statistical remedies were employed. First, a common latent factor (CLF) analysis was conducted following the methodology outlined by Podsakoff, et al. [36]. The standardized loadings of the CLF ranged from 0.39 to 0.60, indicating the presence of some common method variance. However, the magnitude of these loadings is moderate, and the substantive factor loadings remain statistically significant and the overall model fit remained acceptable (CFI = 0.965, RMSEA = 0.055). This suggests that, although common method bias exists to some extent, it is unlikely to materially distort the relationships among the key constructs. Future research may also employ additional techniques, such as marker variable analysis, to further assess and control for common method bias.

4.4. Non-Response Bias

To assess the potential impact of non-response bias, early and late respondents were compared using the procedure recommended by Armstrong and Overton [37]. Independent

sample *t*-tests were conducted to compare early and late respondents on key study variables (IT, KA, CSI, and MF). The results indicated no statistically significant differences between the two groups (all *p*-values > 0.05), suggesting that non-response bias is unlikely to be a concern in this study.

4.5. Structural Model and Hypotheses Testing

The structural model demonstrates an acceptable fit to the data (χ^2/df = 1.524, CFI = 0.947, TLI = 0.930, GFI = 0.904). The RMSEA value is 0.062, with a 90% confidence interval ranging from 0.036 to 0.085, indicating an acceptable fit.

In addition, the model explains 33.5% of the variance in knowledge acquisition (KA), 40.1% in customer–supplier integration (CSI), and 28.9% in manufacturing flexibility (MF), indicating moderate explanatory power.

4.5.1. Direct Relationship

Firm size was included as a control variable in the structural model, with paths specified to the endogenous constructs (knowledge acquisition, customer–supplier integration, and manufacturing flexibility). The results indicate that firm size does not have a significant effect on these variables, and the overall pattern of relationships remains unchanged.

Hypothesis 1 proposed that information technology is associated with knowledge acquisition. The results show that IT has a positive association with KA (β = 0.60, $p < 0.001$). Therefore, H1 is supported.

Hypothesis 2 posited a positive relationship between KA and customer–supplier integration. As shown in the structural model, KA has a positive association with Customer–supplier integration (β = 0.62, $p < 0.001$). Thus, H2 is supported.

Hypothesis 3 proposed that customer–supplier integration is associated with manufacturing flexibility. The findings indicate that customer–supplier integration a has a positive association with MF (β = 0.48, $p < 0.01$). Accordingly, H3 is supported. The results of the hypothesis testing are summarized in Table 5 and Figure 2.

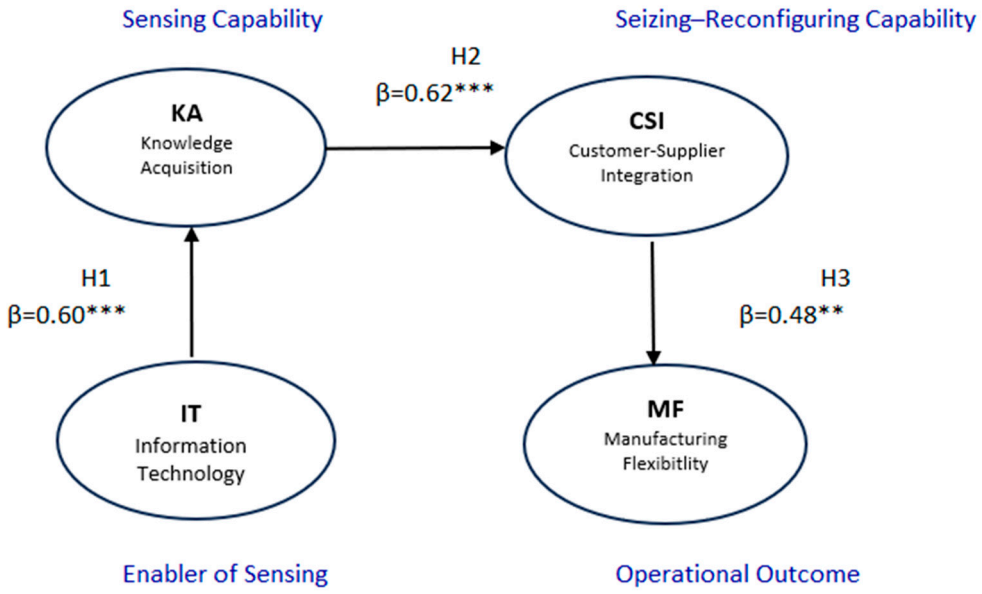


Figure 2. Structural model and standardized path coefficients. ** $p < 0.01$; *** $p < 0.001$.

Table 5. Summary of hypotheses testing.

Construct	Coefficient	*p*-Value	Hypothesis Test
Direct relationships			
H1. Information technology has a positive relationship with knowledge acquisition.	0.60 ***	0.000	Supported
H2. Knowledge acquisition has a positive relationship with customer–supplier integration.	0.62 ***	0.000	Supported
H3. Customer–supplier integration has a positive relationship with manufacturing flexibility.	0.48 **	0.003	Supported
Indirect relationships			
IT → Knowledge acquisition → Customer–Supplier integration → Manufacturing flexibility	0.13 **	0.001	Supported

** $p < 0.01$; *** $p < 0.001$. Note: Direct relationships are reported as standardized path coefficients (β). Indirect relationships are reported as unstandardized bootstrap estimates.

In addition to statistical significance, the magnitude of the standardized coefficients provides further insight into the relative importance of the relationships. The relationship between KA and CSI is the strongest among the proposed paths (β = 0.62), highlighting its critical role in enabling integration with supply chain partners. In comparison, the relationship between IT and KA is slightly lower (β = 0.60), indicating that while IT is an important enabler, its impact is primarily realized through subsequent capability development. Finally, the relationship between CSI and MF is moderate (β = 0.48), suggesting that integration serves as an important mechanism for enhancing flexibility.

From a managerial perspective, these findings suggest that firms should prioritize capability development in a sequential manner, starting with IT-enabled KA, followed by strengthening integration with supply chain partners, in order to effectively enhance MF.

4.5.2. Sequential Mediation Analysis

In addition to the direct relationships hypothesized in H1–H3, this study examined whether KA and customer–supplier integration jointly transmit the relationship between IT and MF. The results indicate that the indirect relationship between IT and MF via KA and CSI is positive and statistically significant (β = 0.13, 95% CI [0.068, 0.261], $p = 0.001$), suggesting the presence of a sequential mediation.

4.5.3. Robustness Check of the Mediation Structure

To further assess whether the relationship between IT and MF is fully or partially mediated, a direct path from IT to MF was added to the structural model. The results show that the direct relationship is not statistically significant (β = 0.26, $p = 0.06$), while the sequential indirect relationship via KA and CSI remains significant (β = 0.13, 95% CI [0.068, 0.261], $p = 0.001$). This pattern of results suggests that the relationship between IT and MF operates primarily through the proposed mediating mechanisms.

In addition, the direct path from KA to MF was examined. The results indicate that this relationship is also non-significant (β = −0.11, $p = 0.50$), confirming that KA does not directly enhance MF. Rather, its influence is realized only through CSI, which serves as the necessary conversion mechanism. These findings collectively support the proposed staged transformation logic. KA represents a sensing-oriented capability that increases understanding of external requirements, but without interorganizational integration such knowledge remains insufficient to alter operational routines. CSI therefore functions as the seizing–reconfiguring capability that translates both IT-enabled information and acquired knowledge into coordinated actions that improve MF.

5. Discussions

This study examined how IT contributes to MF through KA and CSI from a dynamic capability perspective. The findings move beyond a simple input–output logic and reveal a staged capability-building mechanism through which digital resources are transformed into operational flexibility. Rather than acting as a direct performance driver, IT functions as an enabling infrastructure that supports sequential capability development.

First, the absence of a direct IT → MF relationship indicates that digital technology alone does not automatically enhance MF. IT primarily expands information visibility and access, but these informational benefits must be interpreted and mobilized through organizational processes before they can influence production routines. This result suggests that the value of IT is inherently indirect and process-dependent, requiring complementary capabilities to convert digital resources into operational change.

Second, KA also shows no direct relationship with MF, underscoring its role as a sensing-oriented capability rather than an operational change mechanism. Acquired knowledge enhances awareness of customer needs and partner practices, yet such cognitive gains do not by themselves modify schedules, material flows, or resource configurations. Without being embedded into collaborative routines, knowledge remains fragmented and lacks the structural channels needed to affect MF.

Third, CSI emerges as the critical mediator because it provides the seizing–reconfiguring mechanism that operationalizes learning. Through joint planning, synchronized forecasting, and coordinated decision-making, CSI converts externally acquired knowledge into concrete adjustments in production and logistics processes. This explains why both IT and KA require CSI to influence MF: integration aligns interorganizational actions and enables firms to translate information and learning into flexible manufacturing responses.

The mediation analysis reinforces this interpretation. The significant indirect pathway IT → KA → CSI → MF demonstrates that sensing and seizing–reconfiguring capabilities operate jointly across organizational boundaries to produce flexibility. MF therefore arises from a sequential transformation in which IT enables KA, KA facilitates integration, and integration reshapes operational routines.

Overall, these findings highlight that investments in IT alone are insufficient to achieve MF. Firms must cultivate strong KA capabilities and, more importantly, develop integrative relationships with supply chain partners to realize the operational value of digital technologies. By clarifying these mechanisms, the study offers a more nuanced explanation of how digital infrastructure is converted into adaptive manufacturing performance within supply chains.

6. Contributions

6.1. Theoretical Contributions

This study goes beyond empirical verification of relationships among IT capability, knowledge acquisition, and supply chain integration by offering a process-based theoretical explanation grounded in dynamic capability theory. Rather than treating these capabilities as complementary but independent, we conceptualize them as sequential and interdependent elements (sensing → seizing–reconfiguring) through which value may be realized.

First, the study advances dynamic capability theory by revealing a capability-building sequence mechanism linking IT to MF. Drawing on Teece [16], sensing–seizing–reconfiguring framework, this study demonstrates that IT primarily strengthens sensing capabilities through KA, which subsequently enable seizing–reconfiguring capabilities via CSI. This finding shifts the theoretical focus from a technology–performance logic to

a process view of staged transformation, consistent with calls to unpack how dynamic capabilities operate across organizational boundaries.

Second, the study contributes to supply chain integration research by clarifying the distinct role of KA in the formation of interorganizational capabilities. While earlier SCM studies emphasize information sharing enabled by IT, the underlying learning mechanism has remained conceptually ambiguous. By modeling KA as a sensing-oriented capability [10,16], this study demonstrates that integration does not arise automatically from digital connectivity; rather, firms must first develop the capacity to identify, access, and absorb external knowledge before collaborative routines can emerge.

Third, the study extends MF literature by positioning CSI as the seizing–reconfiguring mechanism that converts external learning into operational adaptability. Flexibility has traditionally been treated as an internally generated capability [1,20]. Our findings demonstrate that flexibility increasingly represents a supply-chain-level outcome, emerging from cross-organizational orchestration of plans, forecasts, and processes. This supports the argument that dynamic capabilities in modern supply chains are inherently interfirm rather than firm-centric [13,16], and explains why studies reporting direct IT–flexibility links have produced inconsistent results.

Finally, by integrating IT capability, KA, CSI, and MF into a single model, the study unpacks the black box between digital infrastructure and operational performance. The proposed framework bridges fragmented streams in IT capability, KA [10], and CSI through a coherent dynamic capability lens. This integrative explanation moves beyond static input–output reasoning and offers a process-oriented theory of how digitalization reshapes manufacturing systems in volatile supply chains. This study contributes to the literature by demonstrating that capabilities operate through a sequential transformation process, in which sensing (knowledge acquisition) enables seizing and reconfiguring (customer–supplier integration), ultimately leading to operational outcomes. This process-based perspective extends prior research that has largely treated these capabilities as independent or directly linked to performance.

6.2. Practical Implications

This study also offers several important practical implications for managers and practitioners.

First, the findings highlight that investments in IT alone are insufficient to achieve MF. Consistent with prior studies emphasizing the complementary role of organizational processes, managers should ensure that IT systems are accompanied by practices that actively promote KA and sharing with customers and suppliers. This includes developing data governance routines, cross-functional teams, and incentive systems that encourage the effective use of IT-enabled information.

Second, the results emphasize the strategic importance of CSI in translating knowledge into flexible manufacturing responses. Managers seeking to enhance flexibility should prioritize collaborative practices such as joint forecasting, shared production planning, and coordinated decision-making with supply chain partners (Customer–Supplier Integration). These practices help reduce information delays and misalignment, enabling faster and more effective responses to demand fluctuations and supply disruptions.

Third, the findings suggest that MF should be viewed as a supply chain–level capability, rather than a purely internal operational outcome. In line with dynamic capability theory (Dynamic Capabilities and Strategic Management), firms can improve flexibility by strengthening interorganizational relationships and aligning resources across supply chain partners. This perspective encourages managers to move beyond firm-centric optimization and adopt a more holistic approach to flexibility and resilience.

Overall, the findings suggest a clear prioritization sequence for managers. Firms should first strengthen IT capability to support KA, then develop KA processes, and ultimately focus on enhancing CSI, which serves as the most immediate driver of MF.

7. Limitations and Future Research Directions

This study has some limitations that should be acknowledged.

First, this study relies on cross-sectional perceptual data, which limits the ability to draw strong causal inferences among IT, KA, CSI and MF. Although the proposed relationships are theoretically grounded in dynamic capability theory and tested using structural equation modeling, causal interpretations should be made with caution. Future research could employ longitudinal or panel data to better capture the dynamic and evolutionary nature of capability development over time.

Second, the study relies on self-reported data from single respondents within each firm, which may raise concerns regarding common method bias. While procedural remedies and statistical diagnostics were applied to mitigate this issue, future studies could further strengthen validity by collecting data from multiple informants or combining survey data with objective performance or operational measures.

Third, although the sample includes firms from multiple industries, this study does not explicitly examine potential differences across industries. Given that supply chain practices may vary by industry, future research could employ multi-group analysis to assess the robustness of the findings across different industrial contexts.

Last, IT capability in this study is operationalized using system usage indicators, which may not fully capture broader dimensions such as IT flexibility, managerial capability, or strategic alignment. Future research could incorporate these dimensions to provide a more comprehensive assessment of IT capability. In addition, the measurement of KA includes both external knowledge acquisition and internal learning processes, which may limit the ability to clearly distinguish between these dimensions. Future research could refine the construct by separating these aspects more explicitly.

Differences in institutional environments, technological infrastructure, and supply chain structures across countries and industries may influence how IT and integration mechanisms contribute to MF. Future research could replicate and extend this model in different countries, industries, or supply chain settings to enhance external validity.

8. Conclusions

This study offers several key contributions:

- It proposes a sequential capability development framework that explains how IT enables KA, which in turn facilitates CSI, ultimately leading to enhanced MF.
- It demonstrates that the relationship of IT on manufacturing flexibility is primarily indirect, operating through a structured capability-building process rather than through a direct relationship.
- It extends dynamic capability theory by providing empirical evidence of how sensing (knowledge acquisition), seizing, and reconfiguring (customer–supplier integration) interact as an integrated sequence of capabilities that drive operational outcomes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/logistics10050107/s1, Table S1: Survey Questionnaire.

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