

The relationship between IoT-based information integration, decision-making uncertainty, and supply chain performance

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ABSTRACT

This paper explores the interplay between the Internet of Things (IoT)-based information integration and decision-making uncertainty and their combined impact on supply chain performance. Survey data on 275 supply chain managers is analysed using partial least squares structural equation modelling to illustrate these relationships. IoT-based information integration and decision-making uncertainty is found to be a complex interaction between information accuracy, quality and efficiency; environmental complexity and richness; and demand distortion. The interactions between these factors partially mediate supply chain performance on cost management and production operations. This study provides empirical evidence for the information processing theory-based conceptualisation of the interaction between IoT-based information integration and decision-making uncertainty, and their interactions have a partial mediating role in improving supply chain performance. The research findings help supply chain managers develop a performance-oriented supply chain evaluation system to forecast the outcomes of implementing IoT-based information integration.

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1. Introduction

The complexity of supply chain management introduces significant uncertainty in decision-making for managers (Olan et al. 2024). Furthermore, over the years, consumer demand for personalised products has increased the complexity of supply chains (González-Zapatero et al. 2020). Consequently, there is an increase in decision-making uncertainty, making it difficult for supply chain stakeholders to assess the impact of their decisions on supply chain performance (Nguyen et al. 2023). When decision-making uncertainty increases, supply chain stakeholders require additional information for decision-making, and their information-processing needs increase (Seyedghorban et al. 2020). More specifically, high decision-making uncertainty requires supply chain stakeholders to obtain more accurate and timely information to assess the influence of their decisions on supply chain performance (Wu, Wang, and Rouyer 2019). To meet the growing demand for information processing, practices such as the Internet of Things (IoT)-based information integration have been proposed to enhance information processing capabilities within the supply chain (de Vass, Shee, and Miah 2021). Given the critical role of decision-making in supply chain performance, understanding how IoT integration mitigates uncertainty is not only timely but also crucial for effective

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supply chain governance. In addition, rising uncertainties, such as unpredictable changes in the business environment, have led stakeholders in supply chains to implement IoT to strengthen information integration (Argyropoulou et al. 2024).

IoT-based information integration is an information processing strategy facilitated by IoT implementation that enables firms to collect, select, and share information (Büyüközkan and Göçer 2018). Although the implementation of IoT is growing, it has been demonstrated to be an effective strategy to mitigate the issues caused by decision-making uncertainty in several industries (Vlachos et al. 2023). IoT-based information integration is expected to help reduce both environmental and industry uncertainty. It enhances the accuracy of demand forecasts, helping to reduce demand distortion (Boehmer et al. 2020). It also reduces the impact of environmental uncertainty by facilitating real-time information sharing and enhancing collaboration between supply chain stakeholders (Hughes et al. 2022). Recent developments in AI, data analytics, and IoT integration have aligned with improvements in supply chain performance, enhancing collaboration, facilitating real-time information management, and increasing supply chain transparency (Reaidy et al. 2024). Similarly, Vlachos et al. (2023) highlight that the integration of IoT and other Industry 4.0 technologies helps improve manufacturing systems by achieving lean automation.

While the existing literature has made progress in exploring information integration, gaps exist in its influence and relationship to decision-making uncertainty, as well as supply chain performance. Some studies discuss the impact of IoT on supply chain performance but often neglect the combined influence of decision-making uncertainty (i.e. Boehmer et al. 2020; Sivaparthipan et al. 2023). Others focus on the relationship between information integration and decision-making uncertainty, explaining the resulting impact on operational performance at the firm level (i.e. Fatorachian and Kazemi 2021) rather than at the supply chain level.

In practice, capturing the relationship between IoT-based information integration and decision-making uncertainty and the resulting impact on supply chain performance is complex. Supply chain stakeholders often focus on short-term benefits after implementing IoT-based systems, making it challenging to demonstrate the wider positive effects of such integration (Chang and Sanchez-Loor 2020). Understanding the resulting impact on supply chain performance requires a thorough examination of the interaction of IoT-based information integration with decision-making uncertainty. When uncertainty in decision-making arises, the demand for real-time and accurate information also intensifies (Patrucco et al. 2023; Wu, Wang, and Rouyer 2019). In such scenarios, improved information integration becomes crucial, as it supports rapid and informed decision-making, ultimately enhancing supply chain performance (Ingemarsdotter, Jamsin, and Balkenende 2020; Zdravković et al. 2018). However, to date, the literature has not provided a comprehensive and balanced understanding of the benefits of IoT-based information integration on decision-making uncertainty within the supply chain management literature (Seyedghorban et al. 2020).

Therefore, this research aims to investigate the relationship between IoT-based information integration and decision-making uncertainty at the supply chain level, and to establish the impact of this relationship on supply chain performance. The research questions are thus:

RQ1. What are the main interactions between IoT-based information integration and decision-making uncertainty at a supply chain level?

RQ2. What are the main effects of the interactions between IoT-based information integration and decision-making uncertainty on supply chain performance?

To achieve the research aim, this study used a large-scale survey to collect data (Fernandes et al. 2022). The target population included senior executives and middle-level supply chain managers, as they possess direct knowledge of IoT adoption and its integration within supply chain processes. The analysis was based on Partial Least Square – Structural Equation Modelling (PLS-SEM) (Liao, Dellana, and Falasca 2024; Lusiantoro et al. 2023), helping to verify and identify changes to the IPT-based model.

This study makes several key contributions to the literature on information integration, decision-making uncertainty, and supply chain performance. Firstly, it explains the relationship between IoT-based information integration and decision-making uncertainty by deconstructing their relationship into four empirically validated interactions: (1) information accuracy and environmental complexity, (2) information accuracy and environmental richness, (3) information quality and demand distortion, and (4) information efficiency and demand distortion. The direct impacts of IoT-based information integration and decision-making uncertainty on supply chain performance are also identified. Additionally, the study demonstrates that these interactions partially mediate supply chain performance, elaborating the concept of fit in Information Processing Theory. Furthermore, the study provides novel empirical evidence showing that the early-stage adoption of IoT technologies is insufficient to reduce environmental uncertainty, which is an important factor in achieving financial performance improvements. This suggests that IoT implementation does not provide immediate economic benefits for supply chain stakeholders, but it has been found to yield long-term benefits. These insights contribute to ongoing research on IoT implementation and provide a foundation for future studies to study the interactions between different variables related to IoT implementation.

The rest of the paper is structured as follows. Section 2 details the hypotheses developed following a critical literature review. Section 3 illustrates the research methodology. Section 4 then introduces the results of hypothesis testing and mediation analyses. Section 5 presents the discussion, and the concluding section outlines the research contributions, limitations, and future research directions.

2. Literature review and hypotheses development

To analyse the relationship between IoT-based information integration and decision-making uncertainty, we apply the concept of ‘fit’ from Information Processing Theory (IPT). As demonstrated by Yuen and Thai (2017), fit refers to the interaction between information processing capability and information processing needs. Previous research has shown that information processing needs and information processing capability can be identified within the context of supply chain management and associated strategies (Drazin and Van De Ven 1985). In this paper, we associate decision-making uncertainty with information processing needs. When decision-making uncertainty occurs, the outcome of supply chain stakeholders’ decisions on supply chain performance is difficult to evaluate, frustrating supply chain managers (Laari et al. 2022). These difficulties increase information processing needs in the supply chain (Wang et al. 2021). IoT-based information integration is a supply chain management strategy that firms use to improve information processing capabilities. Extant literature indicates that such integration reduces the difficulty of acquiring real-time information (Seyedghorban et al. 2020) and facilitates information sharing in the supply chain (Li et al. 2025). Consequently, the information processing needs created by decision-making uncertainty are fulfilled (Kache and Seuring 2017). Therefore, the fit between information processing needs and information processing capability becomes the relationship between decision-making uncertainty and IoT-based information integration. Following these arguments, this study anticipates a relationship between IoT-based information integration and decision-making uncertainty, hence the first hypothesis:

Hypothesis 1-1. The implementation of IoT-based information integration interacts with the level of decision-making uncertainty.

2.1. Decision-making uncertainty and information processing needs in SCM

Existing literature indicates that environmental uncertainty and industry uncertainty are the leading causes of increasing information processing needs in complex business environments (Feng,

Zhou, and Matejun 2024; Laguir et al. 2023). Environmental uncertainty refers to unexpected changes in the business environment (Patrucco et al. 2023). It increases complexity and reduces the richness of the available resources. When environmental complexity is high, and the available resources for firms operating within an environment are limited, supply chain stakeholders require additional information to support their decision-making processes (Hofer, Jin, and Knemeyer 2020; Pan, Chen, and Ning 2018). Industry uncertainty occurs during communication between supply chain stakeholders, causing demand distortion, negatively impacting factors such as cost control, inventory management and production control (Ming et al. 2024). To mitigate the negative impacts, firms need to receive information from customers, the market, and other supply chain stakeholders (Li et al. 2025).

2.2. IoT-based information integration and information processing capability in SCM

IoT-based information integration alleviates this challenge by enhancing information collection, improving information selection and facilitating effective information sharing among supply chain participants (Mirzabeiki and Saghiri 2020; Rasool et al. 2023). Consequently, stakeholders' information processing capability improves, satisfying the information processing needs generated by decision-making uncertainties (Kache and Seuring 2017). For instance, the correctness, reliability, and precision of data used for decision-making, which is defined as 'information accuracy', is improved by IoT-based fault detection, for example, identifying a production line failure, increasing the firm's information processing capacity and providing high-level quality management (Abualsaud 2023). IoT-based transmission technologies, such as 5G, guarantee error-minimised information transfer (Koh, Orzes, and Jia 2019). The amount of error in the information is the key measurement for information quality (Gupta et al. 2019). IoT has the potential to support information integration by providing a suitable storage environment for the massive amount of information anticipated and accelerating the information-sharing process in supply chain management (Li et al. 2024b). It has also improved the information efficiency of real-time information sharing by creating an information-sharing platform using cloud technologies (Fatorachian and Kazemi 2021). Consequently, IoT-based information integration can enable real-time data collection from machines, reducing the time required for information collection and improving supply chain efficiency (Veile et al. 2022).

2.3. The relationship between IoT-based information integration and decision-making uncertainty

Established literature on the relationship and key factors in IoT-based information integration and decision-making uncertainty helps develop the following hypotheses.

IoT-based information integration improves information collection accuracy, bringing real-time information to supply chain stakeholders. This provides a flexible information management method, reducing complexity and increasing the richness of the business environment (Argyropoulou et al. 2024). IoT-based information integration significantly enhances the accuracy of information collection by enabling the seamless flow of real-time information across various points in the supply chain (Zhou et al. 2023). Doing so ensures that all stakeholders have access to the resources in the business environment, which is crucial for informed decision-making (Argyropoulou et al. 2024). Additionally, IoT-based information integration facilitates a more dynamic and interconnected business environment by streamlining information management processes (Dev et al. 2021). This, in turn, reduces the complexity often associated with traditional supply chain systems and contributes to a richer, more data-driven operational framework that can better support innovation and competitive advantage. Thus, it can be proposed that:

Hypothesis 1-2. Improving information accuracy minimises the diversity of environmental components in the supply chain.

Hypothesis 1-3. Improving information accuracy enriches the availability of information or resources in the environment.

Previous literature highlights that accurate and reliable information empowers stakeholders to make better-informed decisions, particularly in the realm of demand forecasting (Chien, Kuo, and Lin 2022). With more precise information, companies can predict customer demand with greater accuracy, minimising the likelihood of overproduction or stockouts. This improved forecasting capability is crucial in reducing demand distortion (Zhou et al. 2023). This reduction in variability also leads to cost savings, improved service levels, and stronger relationships between supply chain partners, as each stakeholder operates with reliable and consistent information (Viet, Behdani, and Bloemhof 2018). This leads to the hypothesis that:

Hypothesis 1-4. Improving information accuracy reduces demand fluctuations in the supply chain.

Enhancing the quality of information in supply chain management plays a critical role in reducing environmental uncertainty, which is often a major challenge for businesses operating in complex and dynamic environments. According to existing literature, the reduction of errors in information management ensures that supply chain stakeholders have access to the right amount of information at the right time, allowing them to better anticipate and respond to changes in the market or operational conditions (Wu, Zheng, and Li 2023). Similarly, credible information builds trust among supply chain partners, leading to more effective coordination and collaboration. This optimisation in information quality enhances the utilisation of external resources, such as suppliers, logistics services, and market intelligence, by ensuring that these resources are aligned with the actual needs and conditions of the supply chain. As a result, businesses can effectively meet their information requirements, reducing the impact of environmental complexity and enhancing the richness of the business environment (Lusiantoro et al. 2018). Based on this discussion, this paper proposes the following hypotheses:

Hypothesis 1-5. Improving information quality minimises the diversity of environmental components in the supply chain.

Hypothesis 1-6. Improving information quality enriches the availability of information or resources in the environment.

Similarly, elevating the quality of information within supply chain management significantly minimises information errors, which are often the root cause of inefficiencies and misaligned operations (Birkel and Hartmann 2019). With higher-quality information, stakeholders across the supply chain can rely on more accurate data, reducing the likelihood of overreacting to demand fluctuations (Handfield, Jeong, and Choi 2019). This leads to smoother, more predictable operations and a more resilient supply chain overall (Li et al. 2024a). This leads to the following:

Hypothesis 1-7. Improving information quality reduces demand fluctuation in the supply chain.

In addition, IoT-based information integration significantly enhances information efficiency by streamlining and optimising the process of information sharing across the supply chain. By leveraging IoT technologies, data from various sources (such as sensors, RFID tags, and other smart devices) can be collected, processed, and shared in real time with minimal latency (Ding et al. 2021). This real-time data flow ensures that all stakeholders have access to resources, facilitating effective communication and coordination throughout the supply chain (Scheibe, Mukandwal, and Grawe 2022). When stakeholders have access to timely and accurate information, they are better equipped to analyse situations, anticipate potential disruptions, and respond swiftly to rapid changes or unpredictable events in the business environment (Liu and Lee 2019). By enhancing information efficiency, IoT-based integration helps supply chain participants maintain agility,

reduce the risks associated with uncertainty, and ultimately achieve a more resilient and adaptable supply chain (Doetzer and Pflaum 2021). Therefore, this paper presents the following hypotheses:

Hypothesis 1-8. Improving information efficiency minimises the diversity of environmental components in the supply chain.

Hypothesis 1-9. Improving information efficiency enriches the availability of information or resources in the environment.

Moreover, enhancing information efficiency plays a critical role in reducing demand distortion within the supply chain. By enabling real-time information sharing through IoT-based systems, data is continuously collected and distributed, ensuring all stakeholders have access to the most accurate and up-to-date information (Wang et al. 2016). This real-time flow reduces processing delays, leading to more precise and responsive demand forecasting (Ivanov, Blackhurst, and Das 2021). Consequently, supply chain participants can better synchronise production, inventory, and logistics with actual demand, reducing overreactions and mitigating demand distortion. This paper thus hypothesises:

Hypothesis 1-10. Improving information efficiency reduces demand fluctuation in the supply chain.

2.4. The impact of the relationship between IoT-based information integration and decision-making uncertainty on supply chain performance

Information Processing Theory (IPT) is the theoretical lens for this study. Different from contingency theory and other theories, such as resource-based view or resource orchestration theory, IPT highlighted the concept of fit in supply chain management (Cao et al. 2015). Fit is ‘*the degree to which the needs, demands, goals, objectives, and/or structures of one component are consistent with the other component*’ (Nadler and Tushman 1980, 45). IPT is well-suited for examining how organisations manage information under conditions of uncertainty and complexity, which aligns with the research objective of understanding interactions between information integration and decision-making uncertainty. Information processing theorists have demonstrated that the fit between information processing needs and capabilities enhances supply chain performance (Li et al. 2024a). By applying the theoretical lens of IPT, it is suggested that the relationship between IoT-based information integration and decision-making uncertainty enhances the alignment between information processing needs and capabilities (Shown in Appendix A). This allows supply chain stakeholders to increase resource utilisation and reduce management costs (Singh and Garg 2015). Furthermore, this relationship encourages the adoption of advanced technologies, which can replace manual tasks with automated systems, thereby reducing labour costs and enhancing operational efficiency (Fatorachian and Kazemi 2021). The literature also highlights that this relationship fosters stronger collaboration among supply chain stakeholders. Improved information flow and integration enhance communication and coordination, which smooths processes such as payments, accelerating the flow of capital across the supply chain (Chakuu, Masi, and Godsell 2019). Hence, this paper advances the following hypothesis:

Hypothesis 2. The relationship between IoT-based information integration and decision-making uncertainty positively impacts cost management.

The relationship between IoT-based information integration and decision-making uncertainty also has significant implications for production operations within the supply chain. It enhances supply chain transparency and improves the accuracy of demand forecasting. Thus, stakeholders are more effectively connected and informed throughout the production process (Birkel and Hartmann 2019). As a result, collaboration among stakeholders is strengthened, leading to more effective interaction and quicker access to critical information. This enhanced communication accelerates the overall supply chain response, allowing businesses to react more swiftly to changes in demand or market conditions (Núñez-Merino et al. 2020).

The relationship between IoT integration and decision-making processes facilitates the improvement of production operations. This improvement is reflected in reduced production process times, as accurate and timely information allows for more efficient planning and execution. Additionally, the increased scheduling flexibility that comes from better information flow allows production schedules to be adjusted easily in response to real-time data, leading to agile and responsive production operations (Salam 2017).

Furthermore, enhanced communication and collaboration among supply chain stakeholders contribute to higher forecast accuracy, which is crucial for reducing the likelihood of overproduction, underproduction, or misalignment between supply and demand. This improved accuracy also plays a key role in reducing product defects, as better information flow ensures that quality standards are consistently met throughout the production process (Sanders and Wan 2018). Hence, this paper advances the following hypothesis:

Hypothesis 3. The relationship between IoT-based information integration and decision-making uncertainty positively impacts production operations.

Figure 1 presents the research model, which illustrates the hypothesised relationships capturing the interactions between IoT-based information integration and decision-making uncertainty and the likely impacts on supply chain performance.

3. Research methodology

To achieve the research aim, this study used a large-scale survey to collect data (Fernandes et al. 2022). The target population for this survey included senior executives and middle-level supply chain managers. This target population was selected to ensure all the respondents understand IoT and how IoT-based information integration is implemented in their supply chain. Additional questions, such as ‘What technology have you implemented?’ and ‘To what extent have you implemented IoT in your supply chain?’ are added before the survey to ensure that the IoT implementation in the company is at an early stage.

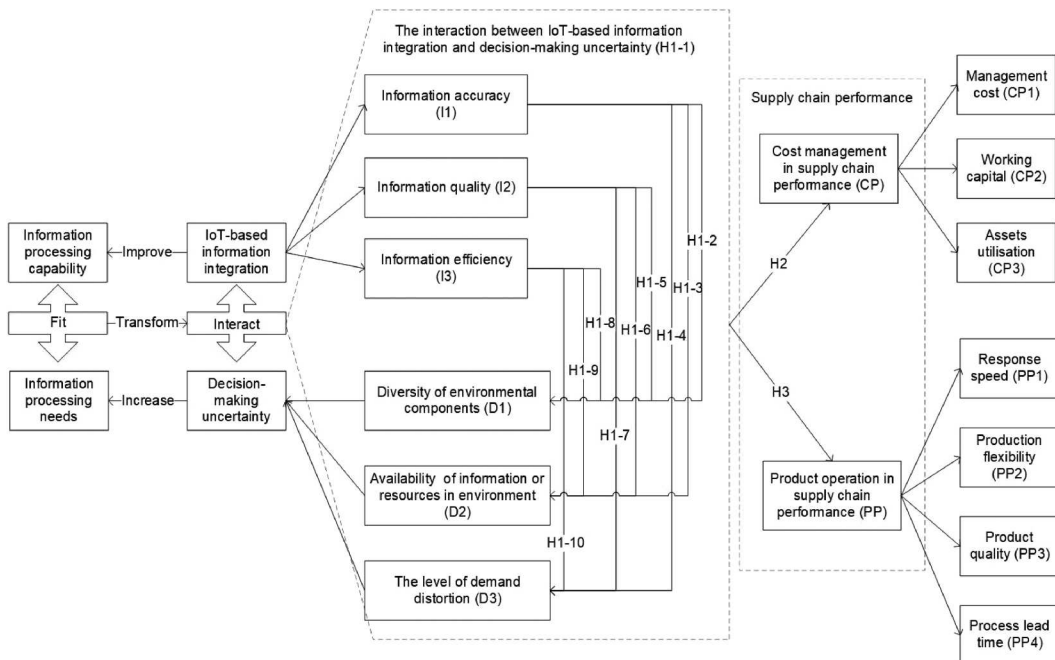


Figure 1. IPT-based relational framework.

The survey instrument was administered in China, and a series of screening questions (e.g. the respondents' job position, company, and industry of practice) were included to identify qualified respondents. Appendix B provides the questionnaire used for the survey. Around 4700 mid-level and senior managers were contacted via email and LinkedIn messages. Regular reminders were sent if no response was received. The survey was run for 3 months from July 2022 to September 2022. A total of 275 usable responses were collected, with a response rate of 5.88%. Although we received fewer responses, the quality of the feedback was high, as the respondents were highly engaged and provided valuable, in-depth insights. Table 1 lists the respondents' demographic information.

PLS-SEM was used to analyse the data. PLS-SEM is used to examine causal relationships between different variables (Liao, Dellana, and Falasca 2024; Lusiantoro et al. 2023), helping to determine whether theory-based models are valid and empirically identify changes to the model. This research set out to test the IPT-based relational framework shown in Figure 1. PLS-SEM was chosen over Covariance-Based Structural Equation Modelling (CB-SEM) due to several methodological and practical considerations. The primary aim of this study was to explore the relationships between IoT-based information integration, decision-making uncertainty, and supply chain performance. This study predicts the relationship model based on IPT and explains the variance (variability) in dependent variables (IoT-based information integration, decision-making uncertainty, and supply chain performance) by analysing the relationships among constructs. This prediction-oriented, variance-based approach aligned with exploratory causal analysis rather than theory confirmation, making PLS-SEM more appropriate (Hair Jr et al. 2021). Furthermore, the model incorporates the concept of fit in IPT but treats the interactions between information integration and decision-making uncertainty as exploratory. The model under investigation also includes complex relationships, and the sample size is relatively small for the CB-SEM model. All these factors make the PLS-SEM approach more efficient, including the potential for formative constructs, which CB-SEM struggles to accommodate (Dash and Paul 2021).

A 7-point Likert scale was used because it results in stronger correlations with *t*-test results (Lewis 1993) and can produce more accurate data (Srivastava and Rogers 2021; Thiagarajan and Sekkizhar 2017) compared to other Likert scales. Content validity was conducted in two steps. First, the items were reviewed by two academics and six practitioners to comment on clarity and appropriateness. Based on their feedback, the items were adjusted for the pilot study. The pilot study was conducted with 16 experts. Their answers were checked and testified with reference to the content validity ratio for the reasonableness of the survey instrument (Lawshe 1975). Multi-set testing and validation of data provide much needed confidence in the survey used for this research. Harman's single-factor test was conducted to assess common method bias. The highest variance found by a single factor was 38.76%, less than 50%. Thus, it is acceptable and indicates that no significant effect of common method bias exists in the dataset. Additionally, this paper conducted wave analysis to test for nonresponse bias (Kumar, Singh, and Modgil 2020). The *t*-values range from -1.593 to 1.419 , with a significance level ranging from 0.188 to 0.982 , indicating no significant differences between the early and the late responses for the construct variables. Hence, it can be concluded that nonresponse bias does not significantly impact this study.

Table 1. Survey demographics.

Respondent's current position	No.	Percentage
Senior Executive	56	20.40%
Mid-level Management	219	79.60%
Function in the supply chain	No.	Percentage
Brand Owner	26	9.50%
Raw Material Supplier	25	9.10%
Manufacturer	184	66.90%
Distributor	40	14.50%

In order to check the construct overlap and discriminant validity, the proposed SEM model (Figure 2) developed from Figure 1 was assessed using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to ensure that the scales of observable factors for latent variables are appropriate and that the model is reliable (Falasca et al. 2022). The detailed definitions of variables are shown in Table 2. EFA was conducted via IBM SPSS Statistics 28.0 to check the fit of the scales. By testing the data with the Bartlett spherical test, the significant results, $KMO = 0.936$, $\chi^2(275) = 2333.286$, $p < 0.000$, indicated that the variables were strongly correlated for the EFA analysis.

Principal Component Analysis (PCA) is a statistical technique used to reduce the dimensionality of a dataset while preserving as much variability (information) as possible (shown in Appendix C). The analysis results reveal that the interactions between information quality and environmental complexity, and between information efficiency and environmental complexity, significantly differ from other factors in the interactions (*Loading of component* < 0.6). Additionally, quality in production performance notably varies from other factors of supply chain performance (*Loading of component* < 0.6). This implies that the interactions between information quality and environmental complexity (I2-D1), as well as between information efficiency and environmental complexity (I3-D1), and the production quality (PP3) are not relevant factors in this model. Consequently, I2-D1, I3-D1, and PP3 were excluded from further analysis.

CFA analysis is designed to assess the validity of scales for observable factors related to each latent variable (shown in Appendix D). Cronbach's α and Composite Reliability were calculated. All constructs demonstrated strong reliability, with Cronbach's α exceeding 0.60 and CR values exceeding 0.80. We also did the Fornell-Larcker Criterion and Cross-Loadings Analysis for a discriminant validity check (see Appendix E). The Fornell-Larcker criterion was met, as $\sqrt{AVE}$ values (bold numbers in Appendix E), which were greater than the inter-construct correlations. Cross-loadings confirmed items loaded highest on their intended constructs. These results support distinctness between constructs.

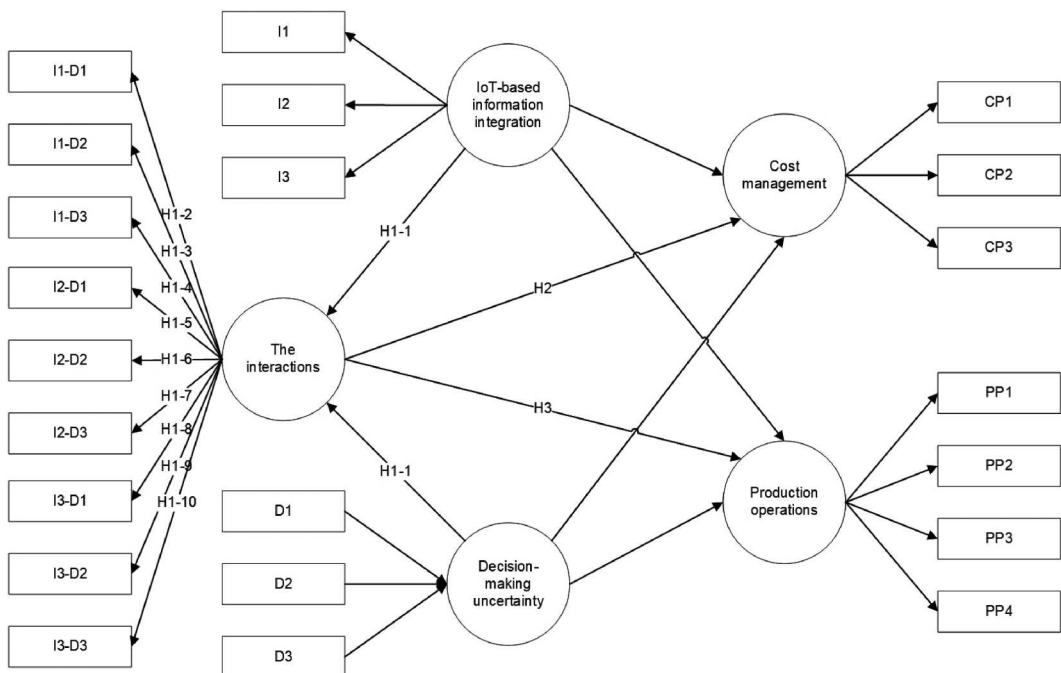


Figure 2. PLS-SEM model.

Table 2. Summary of hypothesis testing.

Hypotheses	Path	Loading	Path coefficient (β)	Standard deviation (STDEV)	<i>t</i> -statistics ($ O/STDEV $)	<i>p</i> -values	Conclusion
H1-1	Decision-making uncertainty → Interactions	–	–0.384	0.050	7.750	0.000	Supported
H1-1	IoT-based information integration → Interactions	–	0.393	0.052	7.593	0.000	Supported
H1-2	I1-D1 ← Interactions	0.721	–	0.036	20.299	0.000	Supported
H1-3	I1-D2 ← Interactions	0.748	–	0.030	25.002	0.000	Supported
H1-4	I1-D3 ← Interactions	0.693	–	–	–	–	Not supported
H1-5	I2-D1 ← Interactions	–	–	–	–	–	Not supported
H1-6	I2-D2 ← Interactions	0.659	–	–	–	–	Not supported
H1-7	I2-D3 ← Interactions	0.775	–	0.028	27.945	0.000	Supported
H1-8	I3-D1 ← Interactions	–	–	–	–	–	Not supported
H1-9	I3-D2 ← Interactions	0.675	–	–	–	–	Not supported
H1-10	I3-D3 ← Interactions	0.797	–	0.024	33.142	0.000	Supported
H2	Interactions → Cost management	–	0.321	0.058	5.575	0.000	Supported
	CP1 ← Cost management	0.815	–	0.021	39.461	0.000	Supported
	CP2 ← Cost management	0.765	–	0.028	26.962	0.000	Supported
	CP3 ← Cost management	0.774	–	0.033	23.442	0.000	Supported
H3	Interactions → Production operations	–	0.309	0.057	5.421	0.000	Supported
	PP1 ← Production operations	0.777	–	0.027	28.972	0.000	Supported
	PP2 ← Production operations	0.749	–	0.034	21.730	0.000	Supported
	PP3 ← Production operations	–	–	–	–	–	Not supported
	PP4 ← Production operations	0.831	–	0.022	38.565	0.000	Supported

Individual consistency reliability was tested via Cronbach's α , the squared multiple correlation coefficient (R^2), and composite reliability (CR). Cronbach's α of the various constructs ranges from 0.682 to 0.823; the R^2 of the latent variables is within a range of 0.824–0.868, indicating that all measures have good reliability (Hair Jr et al. 2021). The elements' outer loadings are also assessed. The detailed result is shown in Appendix E. I1-D3, I2-D2, and I3-D2 were removed because they have lower outer loading in the model (< 0.7) (Hair Jr et al. 2021). For D1, D2, and D3, which are the key factors of decision-making uncertainty impacted by IoT-based information integration, the results indicate that all three factors are key for decision-making uncertainty at the 0.05 level, with an outer loading over 0.7 and a *p*-value smaller than 0.001. Similarly, I1, I2, and I3 were found to be key factors for IoT-based information integration with an outer loading over 0.7 and a *p*-value smaller than 0.001.

The rejected hypotheses (H1-4, H1-5, H1-6, H1-8, H1-9) suggest that not all elements in IoT-based information integration and decision-making interact with each other. At the present level of IoT implementation and the level of decision-making uncertainty, there are no interactions between information accuracy and demand distortion, information quality and environmental uncertainty, and information efficiency and environmental uncertainty. The absence of interaction between specific elements of IoT-based information integration and decision-making uncertainty can be explained through the lens of IPT, which emphasises the importance of alignment or fit between information processing needs and capabilities. In this context, specific capabilities, such as information accuracy, quality, and efficiency, do not effectively address the distinct demands created by specific types of uncertainty, such as demand distortion or environmental complexity and

richness. This misalignment suggests that while IoT enhances the ability to process information in the supply chain, its benefits are contingent on the nature of the uncertainty being addressed. When the type of information provided does not match the type of information needed, the result is a lack of interaction or performance improvement. In addition, the rejection of H3 indicates that product quality is not as important as response speed, production flexibility, and process lead time in product operations when considering the impact of IoT implementation in information integration.

The remaining research hypotheses were analysed using PLS-SEM software (SmartPLS 4.0). The bootstrapping method (5,000 subsamples) was used to evaluate the significance of the standardised path coefficients with respect to the interactions between decision-making uncertainty and IoT-based information integration. Decision-making uncertainty was found to have a significant direct negative effect on the interactions, with a standardised path coefficient of -0.384 and a p -value smaller than 0.001 . IoT-based information integration was found to have a significant direct positive effect on the interactions, with a standardised path coefficient of 0.393 and a p -value smaller than 0.001 . H1-1 is, therefore, empirically supported by the study results. With respect to the interactions, five hypotheses were rejected (shown in Table 3) due to the significant deviations from other factors (H1-5, linked to factor I2-D1; and H1-8, linked to factor I3-D1) and lower loading values in convergent validity (H1-4, linked to factor I1-D3; H1-6, linked to factor and I2-D2; and H1-9, linked to factor I3-D2). Following the same logic, H1-2, H1-3, H1-7, and H1-10 are supported. In addition, the analysis showed that the interactions had a significant direct positive effect on cost management and production operations in supply chain performance. H2 and H3 are, therefore, empirically. The R^2 values of the endogenous latent variables were significant at the 0.001 level.

Based on previous research in PLS-SEM (Hair Jr et al. 2021), the values above 0.45 indicate that the dependent variables (supply chain cost and production operations) are explained by the independent variables (IoT-based information integration, decision-making uncertainty, and alignment) that this paper selects. It is also observed that if factors I1, I1-D1 and I1-D2 are taken out of the model, the impact of the interaction on cost management was found to decline significantly, whereas the impact on production operations remains almost unchanged. Similarly, when factors I2, I3, I2-D3 and I3-D3 are taken out of the model, the impact of the interaction on cost management was found to increase significantly, whereas the impact on production operation decreases. Based on the above findings, the mediating role of the interactions between decision-making uncertainty, IoT-based information integration and supply chain performance (cost management and production operations) were further evaluated. The bootstrap approach proposed by Hair Jr et al. (2021) was used to investigate the mediation.

The results suggest a statistically significant positive relationship between decision-making uncertainty and supply chain performance variables ($p < 0.05$, $p < 0.01$). Similarly, IoT-based information integration and supply chain performance variables also have a statistically significant positive relationship ($p < 0.001$). Furthermore, the model results indicate the existence of a statistically significant relationship between decision-making uncertainty and the proposed mediator (the interactions) ($p < 0.001$), as well as IoT-based information integration and the proposed mediator (the interactions) ($p < 0.001$). Finally, the indirect link between decision-making uncertainty and

Table 3. Summary of mediation analysis.

Effect	Direct	Indirect	Total	Conclusion
Decision-making uncertainty → Cost management	-0.140^*	-0.123^{***}	-0.263^{***}	Partial mediation (competitive)
Decision-making uncertainty → Production process	-0.206^{**}	-0.119^{***}	-0.325^{***}	Partial mediation (competitive)
IoT-based information integration → Cost management	0.361^{***}	0.126^{***}	0.487^{***}	Partial mediation (complementary)
IoT-based information integration → Production process	0.289^{***}	0.122^{***}	0.411^{***}	Partial mediation (complementary)

Note(s): $^{***}p < 0.001$, $^{**}p < 0.01$, $^*p < 0.05$

supply chain performance (cost management and production operations) – through the interactions – and the indirect link between IoT-based information integration and supply chain performance (Cost management and Production operations) – through the interactions – are all found to be statistically significant at the 0.001 level. Therefore, it can be concluded that the interactions partially mediate the connections between decision-making uncertainty, IoT-based information integration, and supply chain performance (Table 3). This result supports H2 and H3.

4. Results

This study also highlights that decision-making uncertainty negatively affects supply chain performance. This result parallels the findings of previous studies (Wu, Wang, and Rouyer 2019) but uniquely proposes specific factors (increasing environmental complexity, low environmental richness, and existing demand fluctuations) that impact supply chain performance and the intensity of that impact (significant negative impact). Further, this paper empirically verifies that IoT-based information integration positively impacts supply chain performance, which is also well supported in the literature (Reaidy et al. 2024). However, our findings go further in demonstrating that implementing IoT-based information integration improves information accuracy, quality, and efficiency. Increased information processing capability helps to fulfil information processing needs and thus improves supply chain performance. In addition, as mentioned in the previous literature (Oluyisola et al. 2022), IoT-based information integration is in the early stages of implementation in supply chain management. IoT implementation can be classified into four stages: implementation in the information collection process (Stage 1), implementation in the information selection process (Stage 2), implementation in the information-sharing process (Stage 3), and implementation in the decision-making process (Stage 4) (Hughes et al. 2022).

Extant research indicates that at the initial implementation stage of IoT-based information integration (Stages 1 and 2), the improvement reduces environmental uncertainty and improves financial performance (Sahin and Topal 2019; Singh 2020). However, according to this study's findings, the improvement of information quality and efficiency only fulfils the information processing needs created by demand distortion and has more impact on production operations than cost management after Stage 3. Thus, it provides an explanation as to why IoT-based information integration does not bring short-term economic benefits to the supply chain but instead yields long-term benefits. This finding aligns with the literature focusing on supply chain performance (García-Alcaraz et al. 2021; Kumar, Singh, and Modgil 2020). This study further illustrates the impact on different aspects of supply chain performance. The findings further illustrate that the interaction between the improvement of information accuracy facilitated by IoT-based information integration and environmental uncertainty (environmental complexity and richness) has a significant impact on both cost management and production operations. Thus, RQ2 is answered. Finally, indirect connections between decision-making uncertainty, IoT-based information integration, and supply chain performance through these interactions were also found. Our framework explains the mediating role of the interactions between IoT-based information integration and decision-making uncertainty on supply chain performance.

5. Discussion and implications

Based on the findings, an evidence-based relational framework is developed as shown in Figure 3, to describe the role of IoT-based information integration and decision-making uncertainty in supply chain performance. This relational framework extends the IPT-based theoretical framework, providing a detailed explanation of the interactions in this relationship and illustrating the relationship's impact on supply chain performance. This study therefore, provides answers to RQ1 and RQ2 based on this evidence-based framework. The results reflect that the negative effect of decision-making uncertainty on the interaction ($\beta = -0.384$) is almost the same as the positive effect of IoT-based

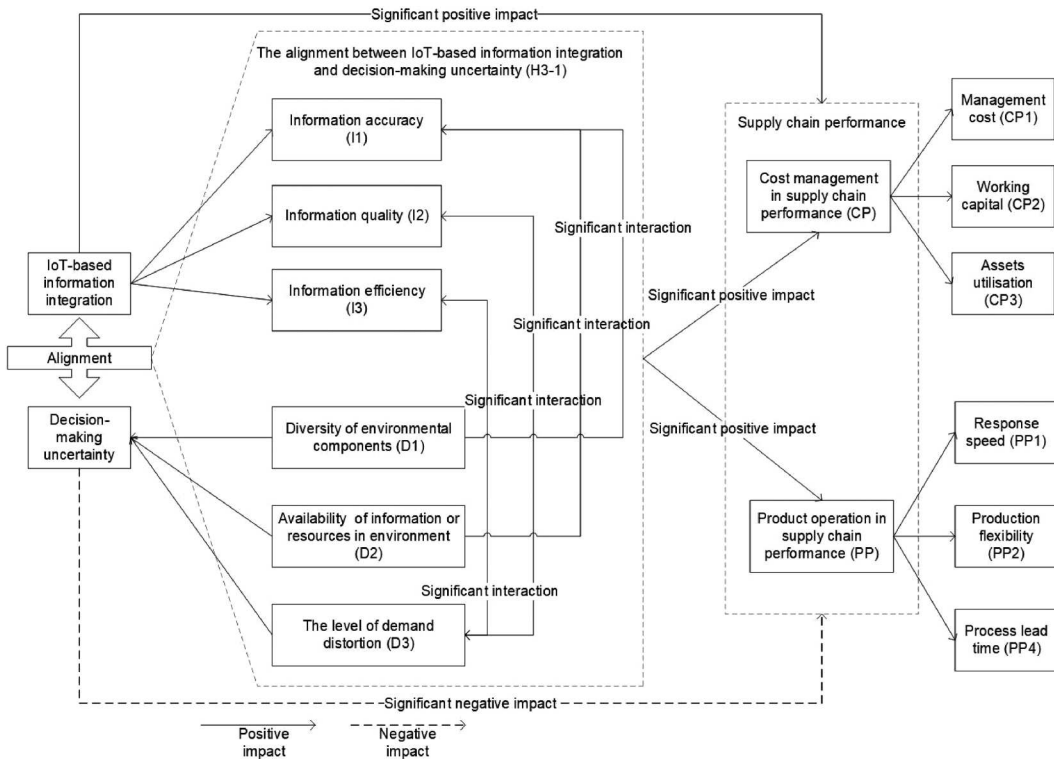


Figure 3. Evidence-based relational framework.

information integration ($\beta = 0.393$) in this model. This similarity suggests that their impacts are complementary. Hence, it can be concluded that the implementation of IoT for information integration is connected to the level of decision-making uncertainty in the supply chain.

This study also investigates the relationship between decision-making uncertainty and IoT-based information integration by identifying the key factors and interactions between IoT-based information integration and decision-making uncertainty. The framework shows that the relationship between decision-making uncertainty and IoT-based information integration can be understood through four key interactions: 1. Information accuracy and environmental complexity; 2. Information accuracy and environmental richness; 3. Information quality and demand distortion; 4. Information efficiency and demand distortion. These interactions highlight how IoT-based information integration enhances a company's ability to process information effectively in uncertain environments. Information quality and information efficiency are improved through IoT-based integration, enabling companies to handle the challenges of demand distortion caused by uncertainties in the industry. Information accuracy, on the other hand, helps to meet the challenges posed by environmental complexity and environmental richness, allowing businesses to process information effectively in uncertain and dynamic environments. This answers RQ1, confirming the connection between IoT-based information integration and decision-making uncertainty and provides a strong explanation of the interactions between them.

6. Conclusion

This paper has focused on the relationship between decision-making uncertainty and IoT-based information integration and its impact on supply chain performance. It uses survey data collected

from supply chain key stakeholders in China to analyse the connection between IoT-based information integration and decision-making uncertainty using a structural equation modelling approach. We first examined the interactions of the key factors in the relationship between decision-making uncertainty and IoT-based information integration. Based on the findings, this paper concludes that a connection arises from the interactions between information accuracy and environmental complexity; information accuracy and environmental richness; information quality and demand distortion; and information efficiency and demand distortion. Later, the interactions' impacts on supply chain performance was evaluated. The interactions between industry uncertainty, information quality and efficiency mainly impact production operations. The interactions between information accuracy and environmental uncertainty have a significant impact on cost management and production operations. The path coefficient analysis also found that decision-making uncertainty and IoT-based information integration have a statistically significant and direct impact on supply chain performance.

6.1. Theoretical implications

This study validates the interactions between the key factors in the relationship between IoT-based information integration and decision-making uncertainty by disassembling the relationship into its individual interactions. Extant studies have used IPT to explain the connection between decision-making uncertainty and IoT-based information integration but haven't explained the micro-level interactions (Seyedghorban et al. 2020). This research is the first empirical study to demonstrate the detailed interactions in the connection between information integration and decision-making uncertainty. It elaborates on the theoretical insights derived from IPT by verifying the key factors in decision-making uncertainty and IoT-based information integration.

The obtained results illustrate that decision-making uncertainty and IoT-based information integration affect supply chain performance both directly and indirectly through their interactions. Thus, they show that the established interactions have a partial mediating role on supply chain performance. By doing so, it provides empirical evidence for the IPT-based conceptual framework. This comprehensive approach provides deeper insights into the dynamics between the considered factors. This study also provides empirical evidence to illustrate the relationship between IoT-based information integration and decision-making uncertainty. The relational framework can help academics to better understand the interactions between information integration and decision-making uncertainty and the role of the IoT in this relationship, along with their wider implications on supply chain performance.

6.2. Managerial implications

The research findings offer supply chain managers the opportunity to develop tools to evaluate the potential of implementing IoT-based information integration. The findings also identify the key factors of IoT-based information integration, decision-making uncertainty, and supply chain performance. Supply chain managers can use these key factors to create key performance indicators (KPIs) and develop a performance-oriented supply chain evaluation system to forecast the outcomes of implementing IoT-based information integration. Such a system offers a practical opportunity to forecast improvements in supply chain performance after implementing IoT for information integration. In addition, the findings in this paper demonstrate that the interactions between decision-making uncertainty and IoT-based information integration positively impact cost management and production operations.

It is established that the interactions between decision-making uncertainty and IoT-based information integration positively impact supply chain costs and production operations in supply chain performance. In practice, supply chain managers may resist implementing new technology in the supply chain due to a lack of ability to forecast short-term benefits (Haddud et al. 2017). This

research indicates that the implementation of IoT at the early stage cannot solve the problems caused by environmental uncertainty, which is critical to improving financial performance; thus, it cannot bring short-term economic benefits to supply chain stakeholders.

6.3. Limitations and future research directions

The study identifies the key factors that visualise the relationship between decision-making uncertainty and IoT-based information integration. However, it has certain limitations. First, there is a limitation associated with endogeneity. This study focuses on a supply chain with a high level of decision-making uncertainty. The situation of lower decision-making uncertainty is not considered. This makes this study a single-informant study. Second, the research question focuses on the changes in supply chain performance after implementing IoT-based information integration. Thus, when selecting samples, this research only considered organisations that have already implemented or planned to implement IoT for information gathering. Organisations without such implementations are excluded. Moreover, during data collection, companies in the Chinese apparel supply chain are in the early stages of implementing IoT; thus, the maturity of implementation is not considered in this stage. Future studies can differentiate the findings based on different implementation stages.

Third, this study examines the interactions between IoT-based information integration and decision-making uncertainty, demonstrating that these interactions enhance supply chain performance. Additional research should explore the prevalence of these interactions in the supply chain. The impact of inconsistency between IoT-based information integration and decision-making uncertainty on supply chain performance is also a valuable area for research. Fourth, the study explains the relationship between uncertainty, IoT, and supply chain performance from a supply chain perspective; therefore, several potential moderating variables, such as organisational culture and individual decision-making autonomy, are not explicitly considered. Future research could benefit from testing the influence of relevant moderators to strengthen the understanding of how organisations process information in complex environments.

Additionally, certain contextual variables, such as firm size, industry type, and the firm's position in its supply chain, are not considered. Thus, the research's explanatory power may be limited, and its generalisability across different industries may be restricted. Future research should consider incorporating these variables to enhance the robustness and applicability of the developed model across various contexts.

This study employed IPT to analyse the relationship between IoT-based information integration, decision-making uncertainty, and supply chain performance. Its exclusive reliance on this framework proves limiting by neglecting the culturally contingent nature of information integration. For instance, cultural values such as leadership style and internal collaboration level influence the decision-making processes (Liao, Dellana, and Falasca 2024). Thus, future studies should integrate IPT with cultural frameworks to capture how cultural norms mediate this relationship.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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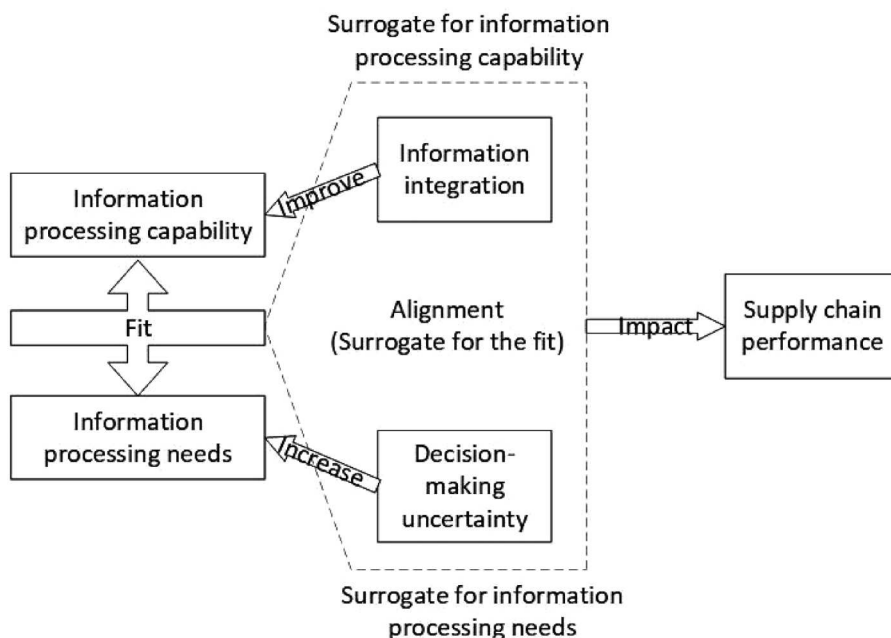
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Appendices

Appendix A: The initial framework of the alignment between IoT-based information integration and decision-making uncertainty



Appendix B: Survey instrument questions and related literature

Questions	Related literature
To what extent does the diversity of component in the business environment increase the requirements of information?	Pan, Chen, and Ning (2018).
To what extent does the availability of resources or information in the business environment increase the requirements of information?	Belhadi et al. (2021)
To what extent does the demand distortion in the supply chain increases the requirements of information?	Belhadi et al. (2021)
To what extent does IoT-based information integration improve information accuracy in the supply chain?	Hwang and Rho (2016); Li and Li (2017)
To what extent does IoT-based information integration improve information quality in the supply chain?	Ma, Wang, and Chen (2017)
To what extent does IoT-based information integration improve information efficiency in the supply chain?	de Vass, Shee, and Miah (2021); Qi and Tao (2019); Belhadi et al. (2021)
To what extent does information accuracy impact the demand distortion in the supply chain?	Jain (2019); Gupta et al. (2019)
To what extent does information quality impact the demand distortion in the supply chain?	Jain (2019); Gupta et al. (2019)
To what extent does information efficiency impact the demand distortion in the supply chain?	Jain (2019); Gupta et al. (2019)
To what extent does information accuracy impact the diversity of component in the business environment?	Jain (2019); Gupta et al. (2019)
To what extent does information quality impact the diversity of component in the business environment?	Jain (2019); Gupta et al. (2019)
To what extent does information efficiency impact the diversity of component in the business environment?	Jain (2019); Gupta et al. (2019)
To what extent does information accuracy impact the availability of resources or information in the business environment?	Jain (2019); Gupta et al. (2019)

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Questions	Related literature
To what extent does information quality impact the availability of resources or information in the business environment?	Jain (2019); Gupta et al. (2019)
To what extent does information efficiency impact the availability of resources or information in the business environment?	Jain (2019); Gupta et al. (2019)
The interactions between IoT-based information integration and decision-making uncertainty reduces the supply chain's management cost.	Singh and Garg (2015); Belhadi et al. (2021)
The interactions between IoT-based information integration and operational decision-making uncertainty increases the company's working capital.	Singh and Garg (2015); Belhadi et al. (2021)
The interactions between IoT-based information integration and decision-making uncertainty improves the supply chain's utilisationsation.	Singh and Garg (2015); Belhadi et al. (2021)
The interactions between IoT-based information integration and decision-making uncertainty accelerates the supply chain's response speed.	Rahman et al. (2022); Fatorachian and Kazemi (2021)
The interactions between IoT-based information integration and decision-making uncertainty improves the supply chain's production flexibility.	Rahman et al. (2022); Fatorachian and Kazemi (2021)
The interactions between IoT-based information integration and operational decision-making uncertainty improves the company's product quality.	Rahman et al. (2022); Fatorachian and Kazemi (2021)
The interactions between IoT-based information integration and decision-making uncertainty improves the efficiency of the supply chain's operation process.	Rahman et al. (2022); Fatorachian and Kazemi (2021)

Appendix C: Components of each latent variable

Latent variables		Elements	Reference	Component			
				1	2	3	4
Decision-making uncertainty	Environmental uncertainty	Environmental complexity (D1)	Rajaguru and Matanda 2013, Pan, Chen, and Ning 2018				0.743
		Environmental richness (D2)				0.521	0.617
	Industry uncertainty	Demand distortion (D3)					0.706
IoT-based information integration	The improvements in information collecting, selecting, and sharing processes	Information accuracy (I1)	Qi and Tao 2019	0.405			0.512
		Information quality (I2)			0.385		0.394
		Information efficiency (I3)					0.787
The interactions between IoT-based information integration and decision-making uncertainty	The interactions between information accuracy and decision-making uncertainty	I1-D1	Li, Zobel, and Russell 2017; Viet, Behdani, and Bloemhof 2018				
		I1-D2					
		I1-D3					
	The interactions between information quality and decision-making uncertainty	I2-D1			0.390	0.391	
		I2-D2			0.615		
		I2-D3			0.490	0.405	
	The interactions between information efficiency and decision-making uncertainty	I3-D1			0.367	0.549	
		I3-D2			0.788		
		I3-D3			0.518		0.326
Supply chain performance	Cost management	Management cost (CP1)	Singh and Garg 2015; Chakuu, Masj, and Godsell 2019	0.692			
		Working capital (CP2)		0.592		0.352	
		Asset utilisation (CP3)		0.629			
	Production operations	Response speed (PP1)	Birkel and Hartmann 2019; Núñez-Merino et al. 2020	0.621			
		Production flexibility (PP2)		0.668			
		Production quality (PP3)			0.349	0.446	0.391

(Continued)

Continued.

Latent variables	Elements	Reference	Component			
			1	2	3	4
	Operation processing (PP4)		0.672			
Extraction Method: Principal component analysis (PCA).			Rotated Component Matrix			
Rotation Method: Varimax with K normalisation.						
a Rotation converged in 6 iterations.						

Appendix D: Consistency reliability and convergent validity

Latent variables	Factors	Loading	VIF	Cronbach's α	Composite Reliability	Average variance extracted (AVE)
Decision-making uncertainty	D1	0.848	1.644	0.712	0.859	0.636
	D2	0.786	1.426			
	D3	0.757	1.315			
IoT-based information integration	I1	0.842	1.422	0.682	0.836	0.611
	I2	0.743	1.249			
	I3	0.756	1.366			
The Interactions	I1D1	0.721	1.444	0.805	0.886	0.578
	I1D2	0.748	1.478			
	I2D3	0.775	1.580			
	I3D3	0.797	1.649			
Cost management	CP1	0.816	1.463	0.688	0.833	0.616
	CP2	0.766	1.271			
	CP3	0.773	1.356			
Production operations	PP1	0.778	1.353	0.691	0.841	0.619
	PP2	0.748	1.282			
	PP4	0.832	1.467			

Appendix E: Discriminant validity

Latent variables	Decision-making uncertainty	Fornell-Larcker criterion		Cost management	Production operations
		IoT-based information integration	Interactions		
Decision-making uncertainty	0.798				
IoT-based information integration	0.482	0.781			
Interactions	0.582	0.617	0.712		
Cost management	0.498	0.614	0.582	0.785	
Production operations	0.523	0.568	0.615	0.733	0.787
Cross-loading					
Latent variables	Decision-making uncertainty	IoT-based information integration	Interactions	Cost management	Production operations
D1	0.848	−0.409	−0.471	−0.411	−0.406
D2	0.787	−0.450	−0.440	−0.418	−0.424
D3	0.756	−0.294	−0.462	−0.363	−0.421
I1	−0.436	0.843	0.520	0.557	0.521
I2	−0.326	0.738	0.426	0.436	0.426
I3	−0.362	0.760	0.397	0.432	0.366
I1D1	−0.496	0.424	0.721	0.439	0.424
I1D2	−0.398	0.460	0.748	0.479	0.432
I2D3	−0.370	0.424	0.775	0.485	0.422
I3D3	−0.477	0.452	0.797	0.454	0.524
CP1	−0.370	0.480	0.500	0.817	0.589
CP2	−0.428	0.512	0.465	0.767	0.599
CP3	−0.374	0.452	0.472	0.771	0.534
PP1	−0.391	0.447	0.469	0.572	0.780
PP2	−0.408	0.419	0.432	0.560	0.747
PP4	−0.435	0.471	0.499	0.597	0.830



DSPACE

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The relationship between IoT-based information integration, decision-making uncertainty, and supply chain performance

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