



YUFEI XUE

The relationship between decision-making uncertainty and  
information integration in FMCG supply chains

SCHOOL OF MANAGEMENT

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Doctor of Philosophy

Academic Year: 2019 - 2023

Supervisor: Dr Nicky Yates

Associate Supervisor: Dr Abhijeet Ghadge

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## **ABSTRACT**

The relationship between decision-making uncertainty and information integration is important for supply chain stakeholders. However, the detailed interactions in this relationship have received limited explanation. This study empirically identifies the key factors in the relationship and investigates their interactions. Based on three papers, the thesis captures the relationships and interactions between decision-making uncertainty and information integration, offering empirical evidence on the nature of these relationships.

The first paper develops a theory-based relational framework for the relationship between decision-making uncertainty and information integration. A systematic literature review (SLR) approach is conducted, and 86 articles published between 2001–2022 are reviewed. The findings support the concept of fit in information processing theory (IPT), demonstrating that information processing needs and capabilities must match to positively impact supply chain performance. The paper also indicates that the high level of environmental and industry uncertainty in decision-making uncertainty increases supply chain stakeholders' willingness to implement information integration. Simultaneously, supply chain stakeholders implement Industry 4.0 information and communication technologies (ICTs) to support technology-based information integration and to reduce the impact of decision-making uncertainty in the supply chain. The relationship between decision-making uncertainty and information integration has also been shown to impact supply chain performance.

The second paper uses the Internet of Things (IoT) to represent ICTs in Industry 4.0. The study conducted a multiple-case study in the fast fashion industry in China to investigate the relationship between decision-making uncertainty and information integration affected by the implementation of the IoT. Consequently, environmental complexity, richness, and the bullwhip effect are identified as the key factors in decision-making uncertainty; information accuracy, quality, efficiency, and security are identified as the key factors in information integration; and management cost and asset utilisation in supply chain costs, alongside response speed, product flexibility, and efficiency in production operations, are identified as supply chain performance. Moreover, the findings highlight that the alignment between decision-making uncertainty and information integration is important and consists of several interactions among environmental complexity, environmental richness, the bullwhip effect, and information accuracy, quality, and efficiency. This research elaborates on the theory-based relational framework developed in Paper 1 and it provides empirical support to several conceptual studies on implementing IoT applications.

The third paper assesses the interactions identified in Paper 2 and their impact on supply chain performance. After analysing the data collected from the supply chain stakeholders of the fast fashion industry in China through structural equation modelling (SEM), the analysis results confirm the importance of key factors in decision-making uncertainty (environmental complexity, environmental richness, and bullwhip effect) and IoT-based information integration (information quality, information accuracy, and information efficiency). The interactions between information accuracy and environmental complexity, information accuracy and environmental richness, information quality and the bullwhip effect, and information efficiency and the bullwhip effect are identified as the key interactions in the alignment between decision-making uncertainty and information integration. The study also emphasises decision-making uncertainty's direct impact on supply chain performance. It concludes that the interactions between decision-making uncertainty and IoT-based information integration partially mediate the relationship. This paper is the first empirical study to explain the detailed interactions between information integration and decision-making uncertainty, and it provides empirical evidence for theoretical associations.

**Keywords**

Internet of Things, Information integration, Decision-making uncertainty, Supply chain performance, Information processing theory

To my beloved wife, Mrs QIUYUAN NIE

To my lovely children, YIHAN XUE and YIMING XUE



*“The way was long, and wrapped in gloom did seem  
As I urged on to seek my vanished dream.”*

—QU YUAN

*Sorrow after Departure*



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## LIST OF ABBREVIATIONS

|       |                                                       |
|-------|-------------------------------------------------------|
| AJG   | Academic journal guide                                |
| AI    | Artificial intelligence                               |
| AVE   | Average variance extracted                            |
| BAM   | British academy of management                         |
| CABS  | Chartered association of business schools             |
| CR    | Composite reliability                                 |
| CFA   | Confirmatory factor analysis                          |
| CPFR  | Collaborative planning, forecasting and replenishment |
| EFA   | Exploratory factor analysis                           |
| EDI   | Electronic data interchange                           |
| FMCG  | Fast-moving consumer goods                            |
| ICT   | Information and communication technology              |
| IoT   | Internet of Things                                    |
| IPT   | Information processing theory                         |
| KPI   | Key performance indicator                             |
| MMI   | Manufacturer managed inventory                        |
| NB    | Narrowband                                            |
| OLSCM | Operations, logistics and supply chain management     |
| PLS   | Partial least squares                                 |
| RBV   | Resource-based view                                   |
| RFID  | Radio frequency identification                        |
| SEM   | Structural equation modelling                         |
| SIG   | Special interest group                                |
| SLR   | Systematic literature review                          |
| VIF   | Variance inflation factor                             |
| VMI   | Vendor managed inventory                              |



# 1 Introduction

## 1.1 Research Background

Making timely and practical decisions improve cost control in supply chain management (Gowda and Subramanya, 2017; Kolinski and Jaskolska, 2018), and such decision-making is a key factor in achieving the performance targets of an organisation (Singh and Garg, 2015). Supply chain managers base decisions on the information they have acquired from other stakeholders in the supply chain, digital data analysis, and their own experiences (Geerts and O’Leary, 2014; Liu et al., 2019). Decision-making uncertainty occurs when the available information is insufficient to support the supply chain manager’s decision-making (Chen et al., 2014; Moyano-Fuentes and Martínez-Jurado, 2016). The decision-making uncertainty increases the difficulty that supply chain managers have in assessing the outcomes of their decisions and creates many issues, such as demand forecast distortion and inventory increase in the supply chain (Gao et al., 2005; Patnayakuni et al., 2006). Such issues strengthen supply chain stakeholders’ requirements for more accurate and timely information for decision-making, thus increasing information processing needs in the supply chain (He et al., 2008; Wu et al., 2019).

The fast-moving consumer goods (FMCG) industry plays an essential role in the growth of the world economy. The size of the FMCG industry’s market is forecasted to reach USD 15 trillion by 2025 (Newswire, 2019). FMCG products such as food, personal care, and apparel are non-durable, low-price products with high consumption rates (Bala and Kumar, 2011; MacArthur, 2013). In recent years, the increasingly stochastic demand for customised and personalised products shortened product lifecycles and increased decision-making uncertainty in the FMCG supply chain (Azevedo and Carvalho, 2012; Ma et al., 2017), negatively impacting supply chain performance. Therefore, FMCG supply chain stakeholders’ information processing needs increase, forcing them to pay close attention to their decision-making processes (Paksoy and Özceylan, 2012; Rademeyer and Lubinsky, 2017).

These increased information processing needs can be met by improvements in information processing capability. Supply chain stakeholders implement information integration to improve information processing capabilities (Wong et al., 2015; Titah et al., 2016; Khanuja and Jain, 2019). Information integration allows supply chain stakeholders to increase their resource utilisation rate, reduce their inventory, and lower management costs (Stefansson, 2002; Singh and Garg, 2015). The fourth industrial revolution (Industry 4.0) is changing how information integration is implemented. It has brought advanced information and communication technology (ICT) and new management concepts (e.g., smart

manufacturing) for supply chain managers to improve their information integration processes (Koh et al., 2019). For instance, a typical ICT application used in information integration is the Internet of Things (IoT) (Harris et al., 2015). The IoT is a network linking physical objects together or a platform integrating useful information into firms' information systems through the internet (de Vass et al., 2018; Thibaud et al., 2018). The IoT supports information integration by improving information collection. Current supply chain management studies maintain that the IoT provides an opportunity for supply chain stakeholders to collect sufficient available and real-time information from supply chain partners. Such information helps organisations to develop new methods to improve customer response, partner collaboration, and supply chain frameworks (Yang et al., 2013; Parry et al., 2016; Li and Li, 2017). Kache and Seuring (2017) identify that the IoT and other advanced technologies can help firms to collect real-time information in the supply chain. Therefore, IoT applications realise the use of real-time information, allowing supply chain stakeholders to optimise information integration by increasing the accuracy and efficiency of information acquisition (Zelbst et al., 2012; Rejeb et al., 2019).

## 1.2 Research Questions and Objectives

Scholars argue that the benefits of IoT in information integration remain uncertain, as firms are not guaranteed short-term financial returns after implementing IoT-based information integration (Hofmann and Rüscher, 2017; Raj et al., 2020). Furthermore, the extant research focusses primarily on individual supply chain functions (inventory management or delivery planning) (Mathaba et al., 2017; Ding et al., 2021). To date, the literature has not provided a comprehensive and balanced understanding of the benefits of information integration on decision-making uncertainty in the FMCG supply chain (Nakandala et al., 2017; Seyedghorban et al., 2020). As supply chain management aims to improve overall supply chain performance (Hung et al., 2011; Fan et al., 2017), holistic perspective is necessary to explain how supply chain performance is influenced by the interaction of information integration and decision-making uncertainty, how decision-making in the FMCG supply chain is affected by information integration, and how information integration is affected by the IoT.

In response to this gap, this thesis seeks to characterise the relationship between information integration and decision-making uncertainty while considering IoT implementations in the FMCG supply chain. It aims to answer the following research question: ***How does the implementation of IoT applications impact the relationship between information integration, decision-making uncertainty, and performance in FMCG supply chains?***

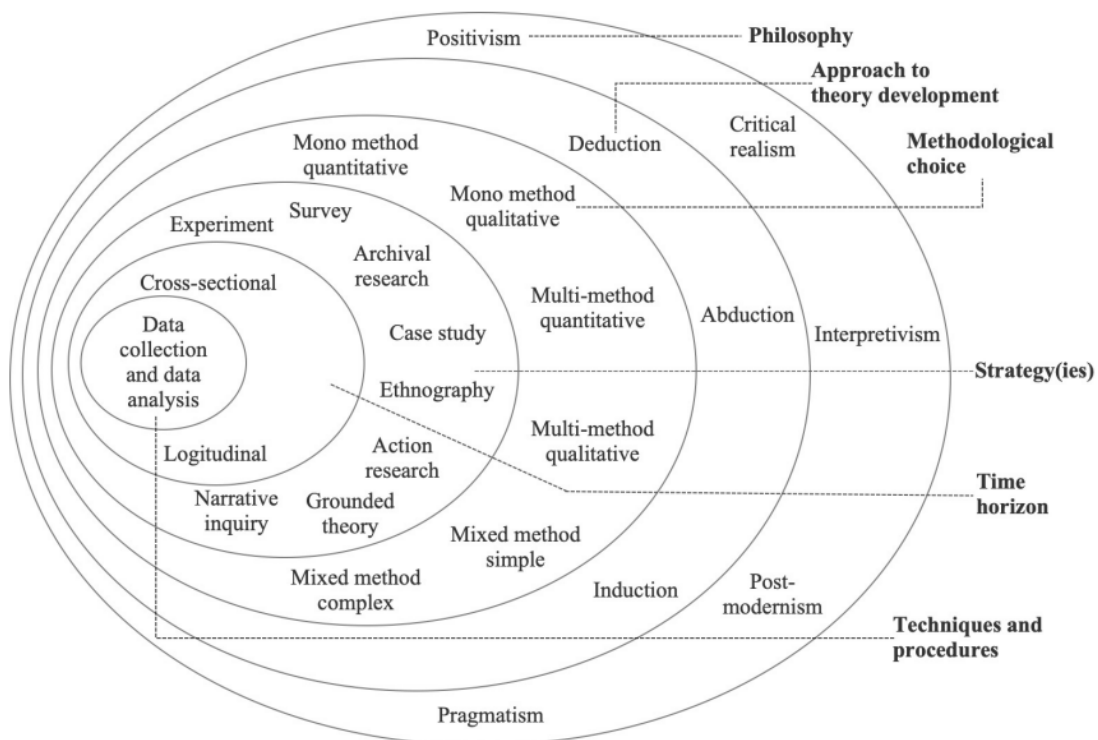
The research question is then subdivided into several sub-questions. Based on those questions, Table 1-1 lists the five objectives of the thesis.

| Sub-questions                                                                                                                                     | Research objectives                                                                                                                                                                                                       | Related paper |
|---------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| SQ1. How does ICT implementation impact the relationship between information integration and decision-making uncertainty in FMCG supply chains?   | <i>Objective 1.</i> To provide an overview of the extant literature on the relationship among ICT applications, information integration, decision-making uncertainty, and supply chain performance in FMCG supply chains. | Paper 1       |
| SQ2. How does the implementation of IoT applications change the relationship between information integration and decision-making uncertainty?     | <i>Objective 2.</i> To identify the key factors in the relationship between information integration and decision-making uncertainty.                                                                                      | Paper 2       |
| SQ3. How do the changes in the relationship between information integration and decision-making uncertainty impact supply chain performance?      | <i>Objective 3.</i> To identify the impact of the key factors on supply chain performance after implementing IoT applications in the FMCG supply chain.                                                                   | Paper 2       |
| SQ4. What are the interactions between IoT-based information integration and decision-making uncertainty?                                         | <i>Objective 4.</i> To evaluate the key factors and interactions in the alignment between information integration and decision-making uncertainty after implementing IoT applications in the FMCG supply chain.           | Paper 3       |
| SQ5. What are the effects of the alignment between IoT-based information integration and decision-making uncertainty on supply chain performance? | <i>Objective 5.</i> To assess the interactions between IoT-based information integration, decision-making uncertainty, and supply chain performance based on the identified factors.                                      | Paper 3       |

**Table 1-1. The sub-questions and related research objectives**

### 1.3 Research Design

The research design follows a step-by-step process proposed by Saunders et al. (2009). A systematic literature review (SLR) is first conducted to formulate the theoretical framework, and then the design of empirical works starts from theory elaboration to the methodology selection (shown in Figure 1-1).



Source: Saunders et al. (2009, p. 130)

**Figure 1-1. The research design process**

### 1.3.1 Research Paradigms of the Thesis

In terms of research paradigms, scholars propose five major philosophies in management research: positivism, critical realism, interpretivism, postmodernism, and pragmatism (Boje et al., 1995; Alvesson and Deetz, 1999; Saunders et al., 2009). Uniquely, critical realism emphasises that understanding the world involves two steps: observation and mental processing (Saunders et al., 2009). Critical realism is suitable to study emerging phenomenon in several disciplines of social science related to supply chain management, including information systems, organisation management, and management science (Downward and Mearman, 2007; Wynn and Williams, 2012; Rotaru et al., 2014). In this study, the implementation of IoT applications is a new area of research and practice, and little is known about it, especially in the context of FMCG supply chains. Objectives 2 and 3 address the observed relationship between decision-making uncertainty and information integration after implementing IoT applications. Objectives 4 and 5 focus on assessing these observations. Thus, this research adopts a critical realist stance.

To develop theory in this work, instead of testing theory with data (as in deduction) or generating theory from data (as in induction), an abductive approach is

selected (Suddaby, 2006). In the abductive approach, data is collected to explore a phenomenon, then themes are identified, and patterns are explained (Saunders et al., 2009). It is also the driving force for the modification and development of the logic of theories, allowing them to cohere with a phenomenon or context (Dubois and Gadde, 2002; Ketokivi and Choi, 2014). To achieve the research objectives, abductive reasoning allowed for the elaboration of the theory on the subject area as a combination of information integration, decision-making uncertainty, and supply chain performance.

### **1.3.2 Empirical Context**

Drawing on the definition of FMCG products by the Chinese Academy of Sciences, the fast fashion sector in the FMCG industry is selected as the target for empirical studies. The studies by Kuylensstierna and Mattisson (2013), Anguelov (2015), Martin (2016), Sun and Shan (2020), and Wei and Jung (2022) also followed the same definition and classified fast fashion products as FMCG products. The fast fashion industry is important to the global economy regarding trade, employment, investment, and revenue (Jeszka, 2015; Ma et al., 2017). The market size has quickly increased over the past decade. Experts predict that the global fast fashion market will grow to about \$163.5 billion in 2025 at a rate of 19% (Research and Markets, 2021). Moreover, customers' consumption behaviour has changed in recent years. For instance, a report from *Business Insider* (McFall-Johnsen, 2019) shows that while people bought 60% more fast fashion products in 2014 than in 2000, they kept the products for only half as long. Recent statistics also show that more than 50% of fast fashion clothes will be discarded within one year of purchase due to fast-moving trends (trvst, 2021).

Recently, decision-making uncertainty in the fast fashion supply chain has increased due to the short life cycle of fast fashion products caused by differentiated and personalised demand (Chen et al., 2014; Moyano-Fuentes and Martínez-Jurado, 2016). These uncertainties arise from a lack of timely information retrieval. To deal with rising uncertainties such as unpredictable change in the business environment, the stakeholders in fast fashion supply chains are implementing IoT applications to strengthen information integration (Azevedo and Carvalho, 2012; Sanders and Wan, 2018; Baruffaldi et al., 2019). Nevertheless, the empirical research on IoT applications that focusses on the relationship between information integration and the decision-making uncertainty of the fast fashion supply chains is limited (Balocco et al., 2011; Karaosman et al., 2020). As the descriptive analysis in Paper 1 shows, all 86 reviewed papers use the concept of the FMCG supply chain. However, only 35 clarified the target industry, and only one focussed on the fast fashion industry. Although there is a rising implementation trend for IoT applications in practice, the research on the

implementation of IoT applications and their related impacts on decision-making uncertainty, information integration, and supply chain performance in the fast fashion industry are underappreciated.

Overall, the fast fashion industry plays an important role in the FMCG global market. A fast fashion supply chain provides trendy apparel every few weeks at reasonable prices and requires a rapid response to emerging trends and frequent changes in product assortments (Caro and Martínez-de-Albéniz, 2015). Manufacturers often use agile production methods to adjust production volumes and product lines based on real-time sales data and market trends (Ma et al., 2017). These supply chain characteristics and the increasing consumer need for personalised product have been affecting information processing needs within the fast fashion supply chain, increasing the decision-making uncertainty making it higher than other FMCG supply chains. In addition, the higher level of decision-making uncertainty makes the fast fashion supply chain require more stable and efficient information processing processes than other FCMG supply chains (Tarallo et al., 2019). This increased requirement strengthens stakeholders' willingness to implement advanced technologies to improve information processing processes (Barnes and Lea-Greenwood, 2006; Chen and Lu, 2021). This increased willingness has led to more cases of implementing IoT applications in the fast fashion supply chain than in other FMCG supply chains (Sabet et al., 2017; Baruffaldi et al., 2019).

Consequently, the issues caused by IoT applications more commonly emerge within the fast fashion supply chain and are related to the research aims of this study. Empirical research aims to gather data and evidence from a real-life phenomenon and use it to support or elaborate theories (Ellinger, Watkins, and Marsick, 2005). Thus, it is worth using the fast fashion supply chain as a context for empirical studies.

### **1.3.3 Thesis Construction**

The thesis divides into five chapters (as shown in Figure 1-2). Three research papers form the main body of the thesis. In Chapter 2, Paper 1 focusses on Objective 1, which is to characterise the relationship between ICT-driven information integration and decision-making uncertainty. An SLR approach is selected to review the literature. A search string is created based on the key sectors in the research question. Relevance and quality criteria are designed based on the research aims and guides of reviewers in several top journals. As a result, 86 journal papers between 2000 to 2022 are selected. An initial theory-based framework is also developed based on information processing theory (IPT). The purpose is to systematically explore the existing literature on the relationship between decision uncertainty and information integration. The descriptive and

thematic analysis results also provide an overview of the role of ICT in this relationship between information integration and decision-making uncertainty, and the relationship's impact on supply chain performance. Finally, a theory-based relational framework is developed, which identifies the relationship between information integration and decision-making uncertainty. Paper 1 indicates that ICTs improve information integration, and that decision-making uncertainty drives the adoption of information integration.

In Chapter 3, Paper 2 connects to Objectives 2 and 3, which aim to enhance the theory-based relational framework introduced in Paper 1 by identifying key factors in decision-making uncertainty, information integration, and supply chain performance. This paper selects the IoT as a representative of ICTs and focusses on the impact of IoT applications on the key factors of information integration, how these impacts change the relationship between information integration and decision-making uncertainty, and how these changes impact supply chain performance. This paper first proposes several factors for each aspect of the relationship between information integration and decision-making uncertainty and formulates a series of propositions. The propositions are verified by a qualitative research approach using a multiple-case study approach based on semi-structured interviews. A template analysis is conducted from the supply chain and stakeholders' views to report the results. The findings of Paper 2 add some of the missing content in the existing literature identified in Paper 1, explain the interactions between IoT-based information integration and decision-making uncertainty, and highlight the impacts of this relationship on supply chain performance.

In Chapter 4, Paper 3 builds on the findings in Paper 2 to address the last two objectives: that is, to assess the detailed interaction between key factors in IoT-based information integration and decision-making uncertainty and the impacts on supply chain performance. A quantitative approach is selected, and data collected based on a large-scale survey from 275 managers in fast fashion supply chains is analysed with a partial least squares structural equation modelling (PLS-SEM) approach. The analysis results illustrate that IoT-based information integration and decision-making uncertainty have significant direct impacts on supply chain costs and production operations in supply chain performance. The alignment between them also directly affects supply chain performance. Moreover, the interactions between information accuracy and environmental complexity, information accuracy and environmental richness, information quality and the bullwhip effect, and information efficiency and the bullwhip effect are identified as the key interactions in the alignment.

Chapter 5 synthesises the findings from the subsequent chapters and discusses the overall contribution. The theoretical and managerial implications of this work

are also reported. Finally, a discussion of the main limitations and some suggestions for future directions of research are offered.

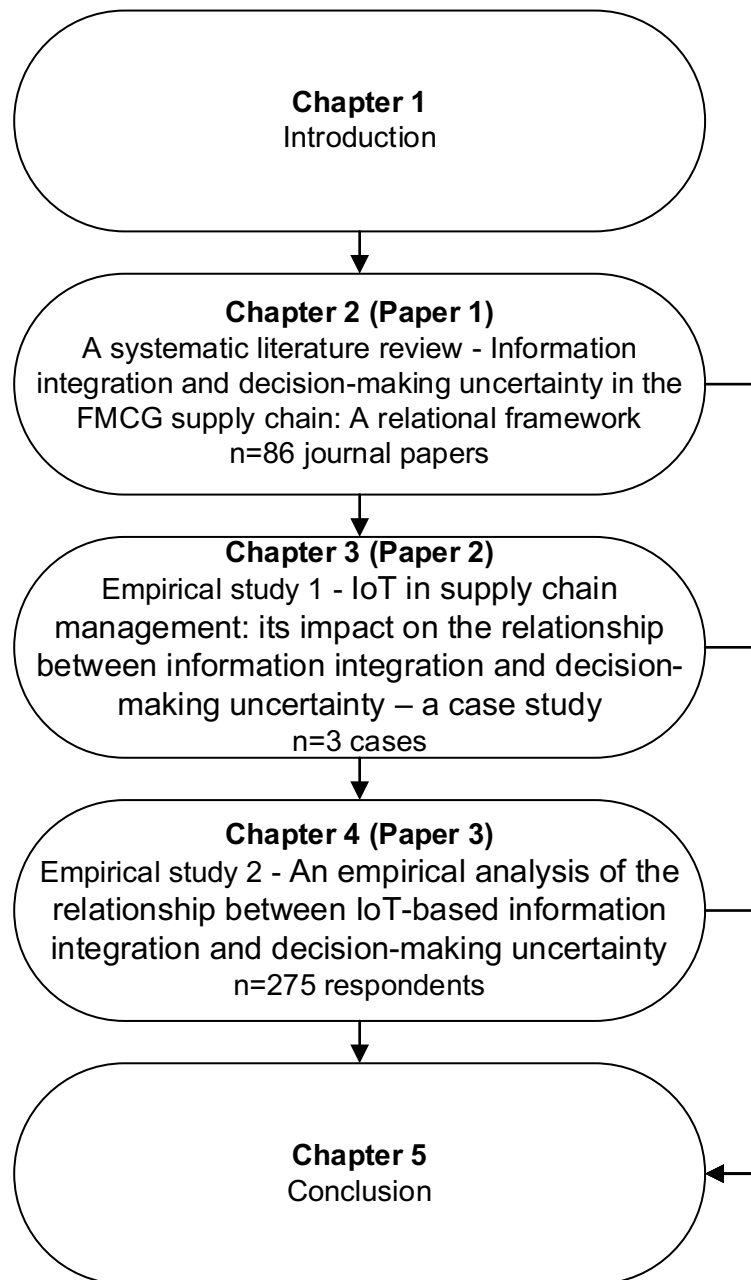


**Figure 1-2. Thesis structure**

## **1.4 Dissemination of the Research**

These three papers fulfil the research aim and objectives collectively, and the research dissemination is listed in Table 1-2.

| Papers                 | Journal paper                                                                                                                                                                                                                                                                                                                               | Conference paper                                                                                                                                                                                                                                                        |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Paper 1<br>(Chapter 2) | <b>In preparation:</b><br>Xue Y, Yates N & Ghadge A (2023), "Information integration and decision-making uncertainty in supply chain management: a relational framework", <i>International Journal of Logistics Management</i>                                                                                                              | Xue Y, Yates N & Ghadge A (2022), "Information integration and decision-making uncertainty in supply chain management: a relational framework." In: 26th Annual Conference of The Chartered Institute of Logistics and Transport, 2022, Birmingham, 7-9 September 2022. |
| Paper 2<br>(Chapter 3) | <b>In preparation:</b><br>Xue Y, Yates N & Ghadge A (2023), "An empirical analysis of the relationship between IoT-based information integration and decision-making uncertainty", <i>International Journal of Operation &amp; Production Management / International Journal of Production Research / Production Planning &amp; Control</i> | Xue Y, Yates N & Ghadge A (2023), "IoT for supply chain management: Impact on the relationship between information integration and decision-making uncertainty". In: 30th EurOMA Conference, 2023, Leuven, 3-5 July, 2023.                                              |
| Paper 3<br>(Chapter 4) |                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                         |

**Table 1-2. Dissemination of the Research**

As the first author of these three papers, I proposed the research topic for the whole thesis, presented the research questions and objectives, designed the research method, collected and analysed the data, and generated the findings. My supervisors, Dr Nicky Yates and Dr Abhijeet Ghadge, who are also the co-authors of these papers, supported this work in developing, revising, and improving the papers, particularly in guiding me to design my qualitative and quantitative data analysis approaches.

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## **2 Paper 1 - Information Integration and Decision-making Uncertainty in the FMCG Supply Chain: A Theory-based Relational Framework**

### **Abstract**

Decision-making uncertainty remains a recurrent challenge for supply chain stakeholders in the fast-moving consumer goods (FMCG) industry. Following the rise of Industry 4.0, interest in information and communication technology (ICT) supported information integration to reduce decision-making uncertainty has increased. However, the effectiveness of information integration in enhancing decision-making uncertainty remains unclear. Thus, this paper aims to characterise the relationship between ICT-driven information integration and decision-making uncertainty. This paper follows a systematic review approach, analysing 86 papers published between 2001 to 2022. Using information processing theory (IPT), a theory-based relational framework characterising the relationship between information integration and decision-making uncertainty is developed. The study results confirm that the relationship between ICT-driven information integration and decision-making uncertainty aligns with the IPT-derived concept of fit. Further, the situational level of decision-making uncertainty drives the information processing needs, which in turn governs the degree to which improving information processing capability will improve performance. From a practitioner's viewpoint, findings provide guidance for supply chain managers when implementing information integration practices in FMCG supply chains.

**Keywords:** Information integration; Decision-making uncertainty; Information and communication technologies; Supply chain collaboration; Information processing theory; Systematic literature review

## 2.1 Introduction

The fast-moving consumer goods (FMCG) market has a large proportion in the world economy. In 2031, the FMCG market is expected to account for 46% of the global market (Shankar, 2023). FMCG products (e.g., food, personal care, and apparel) are characterised by their lack of durability, low price, and high rate of consumption (Bala and Kumar, 2011; MacArthur, 2013). These characteristics increase decision-making uncertainty in the FMCG supply chain by increasing business environmental dynamism (Chen, 2014; Moyano-Fuentes and Martínez-Jurado, 2016). Reflecting the frequency of business environmental changes (Achrol and Stern, 1988), business environmental dynamism determines the complexity and volatility of the business environment (Raven et al., 1994). When business environmental dynamism is high, decision-making uncertainty increases due to the business environment's complexity or volatility (Johnson and Pharr, 1997; Plötner et al., 2013), negatively impacting supply chain performance. For example, decision-making uncertainty is likely to cause demand forecast distortion and to increase inventory in unstable circumstances (e.g., with fluctuations in customer demand) (Gao et al., 2005; Chen, 2014). Therefore, FMCG supply chain stakeholders must attend closely to their decision-making processes to support the supply chain operation overall in a highly volatile business environment (Schmidt and Wilhelm, 2000; Paksoy and Özceylan, 2012; Rademeyer and Lubinsky, 2017).

The extant research stresses that information integration supports FMCG supply chain stakeholders in overcoming decision-making uncertainty and in improving supply chain performance (Valos et al., 2017). Today, Industry 4.0 brings advanced information and communication technology (ICT) and new management concepts (e.g., smart manufacturing) to the FMCG supply chain. Supply chain managers apply these new approaches to support information integration and to improve their decision-making processes (Koh et al., 2019). Firms that adopt Industry 4.0 technologies can improve their information processing capability in the competitive environment (Khajavi et al., 2015; Porter and Heppelmann, 2015). For instance, the implementation of ICTs, such as

Internet of Things (IoT), reduces the difficulty of acquiring information by improving real-time information availability (Seyedghorban et al., 2020), facilitating the cooperation between supply chain stakeholders (Odważny et al., 2018), and thus supporting information integration (Pérez-López et al., 2019). These improvements allow managers to acquire real-time information and to communicate with others more quickly, making the whole supply chain network transparent.

Nevertheless, scholars argue that the benefits of ICT in information integration remain uncertain, as firms are not guaranteed short-term financial returns after implementing ICT-based information integration (Hofmann and Rüsch, 2017; Raj et al., 2020). Furthermore, the extant research focusses primarily on individual supply chain functions (e.g., inventory management or delivery planning). This is not conducive to achieving a comprehensive and balanced understanding of the benefits of information integration on decision-making uncertainty in supply chain management (Nakandala et al., 2017; Seyedghorban et al., 2020). Since the goal of supply chain management is to improve performance of the supply chain (Hung et al., 2011; Fan et al., 2017), a holistic perspective is needed to explain how decision-making in the FMCG supply chain is affected by information integration and how their interaction influences the supply chain performance.

In response to this gap, this study conducts a systematic literature review (SLR) to characterise the relationship between information integration and decision-making uncertainty, while considering ICT implementations in the FMCG supply chain. This paper seeks to answer the following research question: ***How does ICT implementation impact the relationship between information integration and decision-making uncertainty in supply chain management?*** Information processing theory (IPT) states that firms are systems that process information (Galbraith, 1973). The performance of a firm is then determined by the fit between a firm's information processing capabilities and its information-processing needs (Daft and Lengel, 1986; Tushman and Nadler, 1980). Embedding these principles, this study views the supply chain as a system, simplifying the relationship between decision-making uncertainty and information

integration based on the following assumptions: (1) the relationship between decision-making uncertainty and information integration corresponds to the concept of fit in IPT, and (2) the impact of this fit on supply chain performance corresponds to the fit between information processing capability and information processing needs. By considering the effects of ICT on the fit between uncertainty and information integration, this paper proposes a theory-based relational framework characterising the relationship between ICT-supported information integration and decision-making uncertainty in the FMCG supply chain and propose a set of future research directions.

The paper is organised as follows. In Section 2.2, the research background to the key concepts on which the paper is built is provided. In Section 2.3, the theoretical lens is discussed, and the initial theoretical framework is proposed. In Section 2.4, the SLR methodology is introduced. In Section 2.5 and Section 2.6, the results of the literature review are discussed following descriptive and thematic analysis. In Section 2.7, the theory-based relational framework for the relationship between information integration, ICT, and decision-making uncertainty is developed and discussed, and future research directions are presented. Section 2.8 concludes the study.

## **2.2 Research Background**

This section introduces the three main concepts on which the study is built: decision-making uncertainty, information integration, and ICT implementation.

### **2.2.1 Decision-Making Uncertainty in the FMCG Supply Chain**

Following the seminal work of Duncan (1972), scholars categorise decision-making uncertainty into environmental, industry, and firm uncertainty (Tseng and Lee, 2010; Kuklinski et al., 2012; Sniazhko, 2019). For the FMCG supply chain, environmental uncertainty refers to the unexpected changes in the business environment (Rajaguru and Matanda, 2013). Scholars indicate that environmental uncertainty increases the difficulty of forecasting the outcomes of a decision and is an essential external driver of information integration (Li and

Lin, 2006; Wong et al., 2011; Zimmermann et al., 2020). In the FMCG supply chain, industry uncertainty emerges in the interactions between supply chain stakeholders, such as with demand distortion and unpredictable competition (Huo et al., 2014; Ma and Ma, 2017). Issues caused by industry uncertainty (e.g., the bullwhip effect) negatively impact supply chain performance by increasing both forecasting difficulty and inventory (Mbhele and Phiri, 2014; Lu et al., 2017). Firm uncertainty is generated in a supply chain stakeholder's operational process (Li and Lin, 2006). One issue typically related to this form of uncertainty arises from technology implementation in the FMCG supply chain. The short-term financial outcome of implementing new technology is difficult to assess, reducing managers' willingness to implement it and causing delays in product innovation related to technology implementation (Lin and Lin, 2014; Mital et al., 2018).

These three aspects are interrelated. For example, the FMCG supply chain is becoming increasingly global, making competition between FMCG supply chains also less domestic and more global (Sahay and Mohan, 2003). The resulting fierce competition accelerates technology development, which creates firm uncertainty and delays production (Li and Lin, 2006). Such delays increase the demand distortion experienced in the FMCG supply chain, thereby also raising industry uncertainty (Disney et al., 2004; Adenso-Díaz et al., 2012). Consequently, increasing decision-making uncertainty challenges supply chain stakeholders evaluating the outcomes of the decisions they have made to preserve or improve supply chain performance (Raven et al., 1994; Wu et al., 2019).

### **2.2.2 Information Integration in the FMCG Supply Chain**

Data (e.g., orders, inventory details, bills of materials, reports of machines) and other materials (emails, dialog, video, etc.) that are processed and exchanged by supply chain stakeholders constitute the information shared in the FMCG supply chain (Scott and Rogova, 2004; Peng et al., 2011; Huo et al., 2016). In other words, data becomes information following its collection, selection, synthesis, and analysis. Information integration is important to improve supply chain performance in many industries (Nakandala et al., 2017). It has been shown to

reduce decision-making uncertainty by generating real-time information and accelerating information processing and sharing in the supply chain (Patnayakuni et al., 2006; Li et al., 2009; Mirzabeiki and Saghiri, 2020).

Information integration is the measure that supply chain stakeholders adopt to process information. Scholars are constantly updating the definition of information integration. Lee (2000) indicates that information integration represents the information-sharing process between supply chain stakeholders. Academic opinion is divided on this definition, however. Some scholars propose that information integration is instead the infrastructure (hardware or equipment) that improves information processing capabilities in the supply chain (Grover and Saeed, 2007; Wong et al., 2015). Others insist that the information processing methods such as information exchange, communication, and collaboration across the supply chain are the foundation of information integration (Danese, 2006; Büyüközkan and Göçer, 2018). Synthesising these definitions, this research defines information integration as the processes (or methods) required to collect, select, and share information, including the necessary infrastructure.

In the FMCG supply chain, scholars have demonstrated that information integration is vital for supply chain stakeholders to collaborate, especially the information-sharing process (Kembro et al., 2014; Li and Zhang, 2015). For instance, Hu and Wang (2019) study the role of information-sharing platforms for a food and beverage supply chain, indicating that real-time information sharing strengthens the relationship among firms, suppliers, and customers, supporting the decision-making process in the supply chain. Similarly, Kumar et al. (2020) conducted a survey-based study in the agri-food supply chain, and their findings indicate that information sharing improves organisational performance by reducing costs and optimising resource utilisation, for example.

### **2.2.3 ICT Implementation in the FMCG Supply Chain**

ICTs are the devices, techniques, and systems that allow users to manage and share information simultaneously (Pérez-López et al., 2019). The implementation of ICTs in FMCG supply chain has been shown both to aid and to hinder information integration in supply chain management (Datta and Christopher,

2011; Mirzabeiki and Saghiri, 2020). Supply chain management studies have found that the implementation of one typical ICT application, the IoT, provides an opportunity to collect increased volumes of information from supply chain partners. Such information helps organisations develop new methods to improve customer response and build collaboration (Pang et al., 2015; Thibaud et al., 2018; Verdouw et al., 2018). Further, Kache and Seuring (2017) find that the IoT and other advanced technologies (e.g., Digital Twins) can help firms to collect real-time information in the supply chain. Therefore, the ability of ICTs to collect real-time information provides supply chain stakeholders an opportunity to optimise information integration by increasing the accuracy and efficiency of information acquisition (Zelbst et al., 2012; Rejeb et al., 2019).

Meanwhile, the high costs and technical issues associated with ICTs erect barriers to ICT implementation in the FMCG supply chain (Rajaguru and Matanda, 2013). The implementation costs of an ICT solution include equipment (hardware and software), training, operational, maintenance, and so forth (Remenyi et al., 2007). All require substantial investment. For instance, Walmart Canada has invested \$3.5 billion in IoT and related technologies in the past five years (Blackman, 2020). Furthermore, the lack of uniform standards complicates the connection ICT into existing information systems in the supply chain (Bottani and Rizzi, 2008). Therefore, although ICT-based information integration may be valuable in supply chain management, the associated risks challenge its implementation.

## **2.3 Theoretical Lens**

IPT is adopted as a theoretical basis for this review. Developed from contingency theory, it further develops the concept of fit proposed in contingency theory (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” (Tushman and Nadler, 1980, p. 45). The concept of fit implies that performance improves as a result of that fit (Tosi and Slocum, 1984). IPT proposes that a firm’s capability to process received and shared information is critical for that firm to deal with its uncertainties (Yuen and Thai, 2017). To improve firm performance,

the amount and richness of information that the organisation acquires must match the level of uncertainty it faces (Daft and Lengel, 1986).

Işık's (2010) research in this field indicates that also the information processing capability of an organisation must fit the level of uncertainty; otherwise, the lack of fit lowers performance. Other scholars add that IPT views a firm as a system that processes information acquired from outside. To reduce uncertainty and increase performance, firms must improve their information processing capability (Fan et al., 2017; Jain et al., 2017; Gupta et al., 2019). An initial theoretical framework is generated (Figure 1) which embeds the research question in IPT. The first aspect in the research question, information integration implementation, is recognised as an approach that improves an organisation's information processing capability (Wong et al., 2015; Titah et al., 2016).

The second aspect of the research question, decision-making uncertainty, increases information processing needs in supply chain management (Wong et al., 2011; Shamir and Shin, 2018; Wu et al., 2019). IPT indicates that to improve supply chain performance, information processing needs and information processing capability must align (Premkumar et al., 2005; Cegielski et al., 2012). Thus, to improve their performance, supply chain stakeholders must ensure that their level of information integration fits with the decision-making uncertainty they experience.

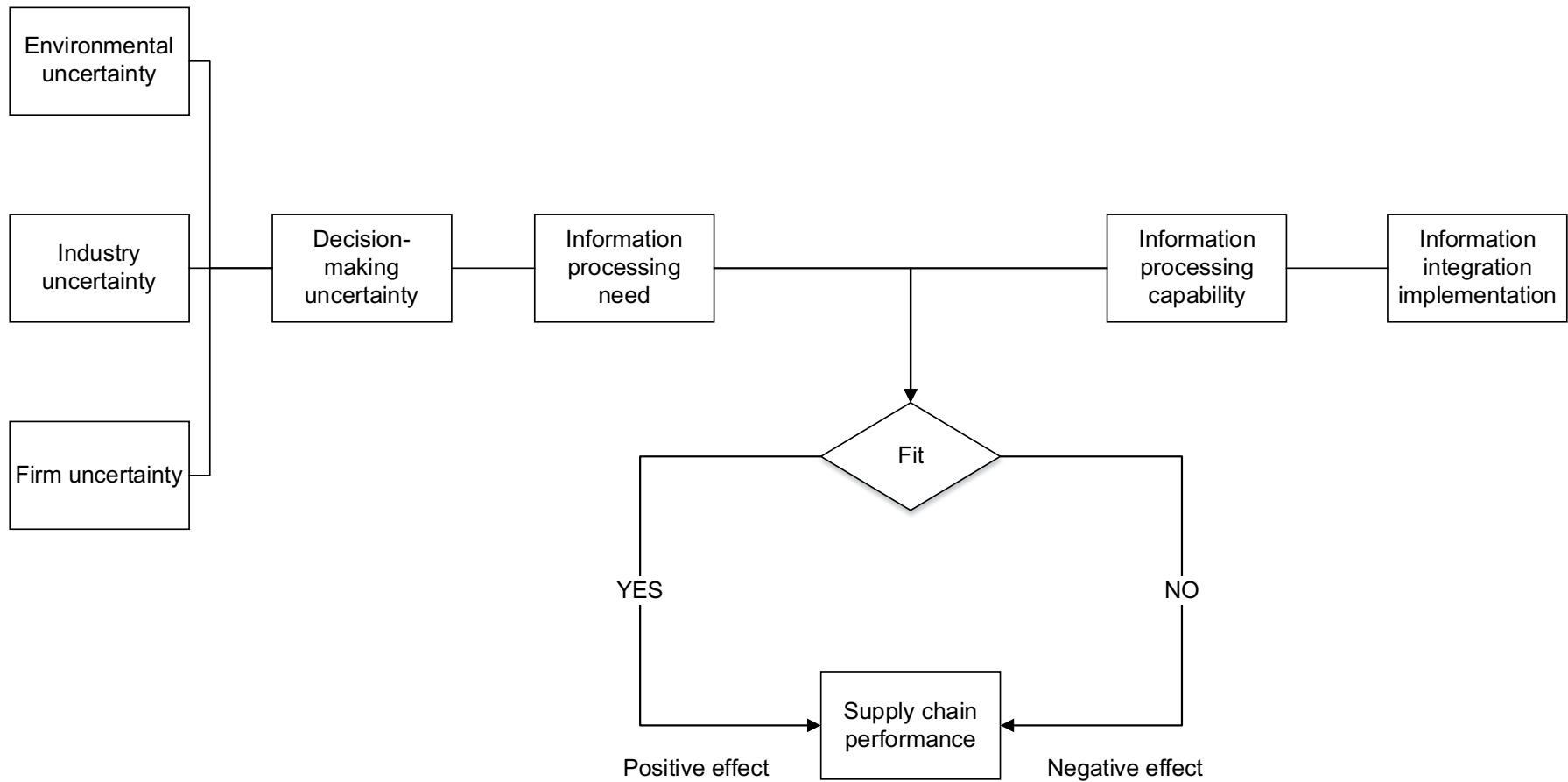


**Figure 2-1. The initial theoretical framework (synthesised from Işık, 2010; Fan et al., 2017; Jain et al., 2017; Gupta et al., 2019)**

## **2.4 Review Methodology**

This paper adopted the SLR approach by following reasons. This study explores the research area intersecting supply chain management, information management, and decision-making. Abundant literature exists for each research area. To filter relevant work, the SLR approach is recommended (Tranfield et al., 2003; Durach et al., 2017). A systematic review is more transparent and replicable than is a narrative review (Corallo et al., 2020; Kumar et al., 2020). SLR approach is also a selective review method that helps to identify and assess relevant literature efficiently in related research fields (Braz et al., 2018; Osterrieder et al., 2020). Several researchers in the management research field have affirmed Tranfield's and Durach's review processes as scientific, repeatable, unbiased, transparent, and rigorous (Friday et al., 2018; Jaghbeer et al., 2020; Núñez-Merino et al., 2020).

### **2.4.1 Searching and Locating Literature**

Keywords were selected based on the review question and on the definitions of decision-making uncertainty, information integration, and ICT discussed in Section 2.2. The keywords used were "information technology", "information integration", "decision-making uncertainty", and "supply chain". Boolean connectors (OR, AND) and synonyms of the keywords were used to create the search strings.

| Keywords                                    | Search string                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Information communication technology</i> | <i>and</i> “information technolog*” or “IT” or “information communication technolog*” or “ICT” or “information system” AND “Information integrat*” or “information shar*” AND “decision making” or “decision-making” or “decision making process” or “decision-making process” or decision* AND Uncertainty or ambiguity or dynamism or instability or equivocality AND “supply chain*” or “value chain*” or “supply network” or “supply chain management” or “SC” or “SCM” or logistic |
| <i>Information integration</i>              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <i>Decision making</i>                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <i>Uncertainty</i>                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <i>Supply chain</i>                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

**Table 2-1. Keywords and search string**

Table 1 lists the selected keywords and search strings. The three databases EBSCO, ABI, and SCOPUS were selected to ensure comprehensive literature coverage in related research areas. To ensure the reliability of the literature, academic peer-reviewed journals were the main target in the search. The search period was limited to the period of January 2000–June 2022 since the information integration research in supply chain management is limited prior to 2000 (only 5 papers found, each without much relevance to the study). The search strings were applied to search the full text of the papers, and the papers were selected following the relevance criteria (see Table A- 1). In the first search of the databases, 13,878 articles were identified. After applying the relevance criteria to screen the title and abstract of each article, and after eliminating duplicates, 472 papers remained for further investigation.

## 2.4.2 Study Selection and Evaluation

First, the relevance criteria were applied to review the introductions and conclusions of these 472 papers, assessing their relevance to the topic of this review, of which 189 papers were selected. Quality assessment criteria were created to evaluate these 189 papers (see Table A- 2). The quality assessment criteria is based on the guides of reviewers in the *European Journal of*

*Operational Research*, *Journal of Management Information Systems* and *International Journal of Operations & Production Management*, Tranfield et al.'s research (2003), and Durach et al.'s research (2017). Each article was scored (0–3) based on six elements: robustness of theory, implications for practice, methodology and data supporting arguments, result, conclusion, and contribution. The score for each element sums to the total score for the article. Papers scoring less than 10 (out of 18) were excluded, as were those scoring 0 in any one of the last four elements. In general, the criteria recognised that a good article may not adopt theories or have links to practice, but it should have an appropriate research method, exact research result, logical conclusion, and meaningful contributions (Robson et al., 2015; Bagchi et al., 2017). This approach reduced the number of articles to 80. A search of paper citations and references identified six more papers, making the final set of articles 86. Figure 2-2 illustrates the literature search and selection process.

### **2.4.3 Analysis and Synthesis**

The literature analysis was based on a data extraction form and NVivo, qualitative data analysis software that facilitates the analysis of complex data such as interviews, surveys, papers, and so forth (Chang and Graham, 2012; Bergeron and Gaboury, 2020). The data extraction form was used to categorise the articles and to distil the discussion relating to information integration, then the data were imported into NVivo. In NVivo, the content was coded and classified into clusters based on the frequency of occurrence and importance in the discussion. Similar clusters were further consolidated and synthesised into four main clusters: integration drivers, integration benefits, integration drawbacks, and integration implementation. Following the advice in Tranfield et al. (2003) and the guidance of Durach et al. (2017), the analysis is typically divided into two different types: descriptive and thematic.

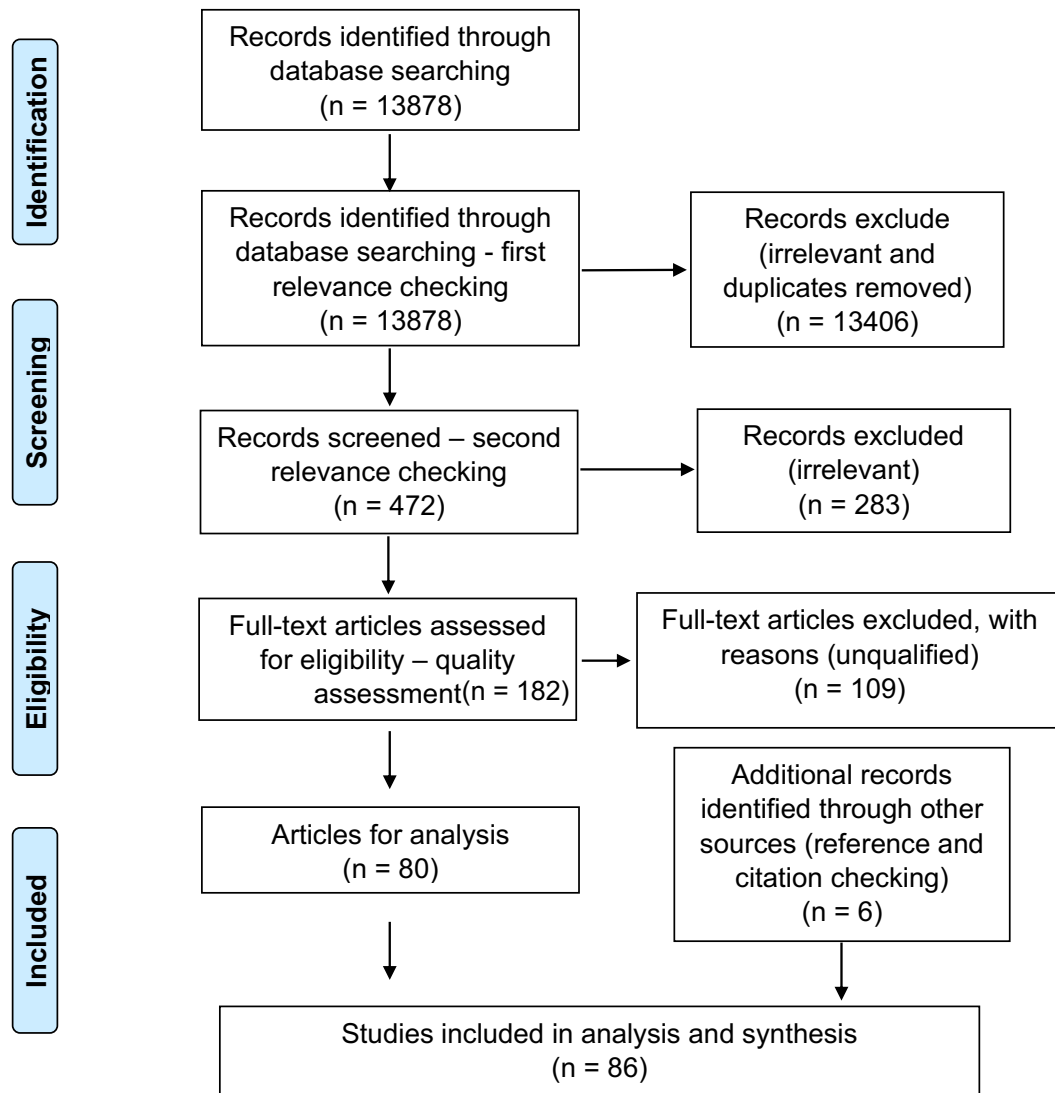


**Figure 2-2. Searching and selection process**

## 2.5 Descriptive Analysis

Descriptive analysis is a deductive approach that helps to classify papers and provides trends in the field of study (Chakuu et al., 2019; Kumar et al., 2020). The 86 papers of the SLR were analysed according to the publication year, distribution of papers in journals, authors, CABS rating, research type, and research method.

Figure 2-3 shows the number of papers per year. The analysis identifies increasing interest in the topic ICT, information integration, and decision-making uncertainty. Over 60% of the papers have been published since 2015.

This finding is consistent with other scholars' findings that the implementation of new information technology, along with related topics, has drawn increasing attention since the proposal of the concept of Industry 4.0 (Parente et al., 2020; Raj et al., 2020). This finding also indicates that information integration and decision-making are highly active research directions in supply chain management, gaining increased attention from researchers and practitioners (Patnayakuni et al., 2006; Samaranayake and Laosirihongthong, 2016).

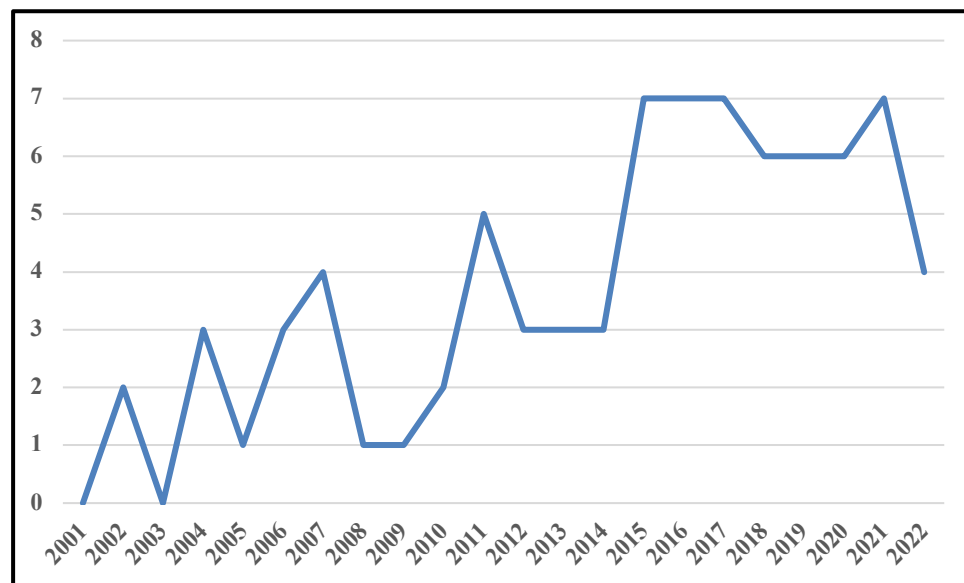


**Figure 2-3. Distribution of papers per year**

The 86 journal papers were published in 47 journals. All of them are AJG-ranked journals (CABS, 2021) by coincidence. As illustrated in the Distribution of papers in journals (Table A- 3), most contributions were published in *International Journal of Production Economics* (10 papers), *International Journal of Physical Distribution and Logistics Management* (7 papers), *Sustainability* (5 papers), and the *European Journal of Operational Research* (4 papers). The spread of publications suggests relevant attention from production- and operation-related journals that focus on production, operations, and supply chain management problems. Accordingly, over half of the papers (47/86) appear in production or operations-related journals.

It can be seen from the descriptive analysis (figure 2-4 to 2-6) that the levels of decision-making uncertainty in FMCG supply chains are not the same. Most of the papers in the literature review stated that in their research, the FMCG sectors are at the normal level of decision-making uncertainty (82%), especially food and household supply chains. In the context of normal decision-making uncertainty level, most of the papers use mathematical modelling to conduct conceptual studies (see Hung et al., 2011; Boos et al., 2013; Mbhele, 2016). As illustrated in Figure 2-5, most contributions focused on the general FMCG (12 papers), food (10 papers), and household (10 papers) sectors.

The research in high decision-making uncertainty contexts is limited, with only 7 (18%) papers (Figure 2-6). The reason is that the implementation of ICT in the FMCG industry is still at an early stage. Although decision-making uncertainty increases to a high level in some of the FMCG sectors, such as the fast fashion supply chain, the application examples in the industry are still limited (Gao, 2017; Keszey, 2017).

Scholars in the sample literature demonstrate that studying a supply chain with normal decision-making uncertainty allows researchers to conduct a more structured and focused study, control the variables to test the impact of specific IoT implementations and compare the performance of a traditional supply chain with an IoT-enabled supply chain more efficiently in a controlled setting with more empirical evidence (Hung et al., 2011; Boos et al., 2013; Mbhele, 2016). In addition, fast fashion is a smaller industry compared to the supply chains in a normal uncertainty level such as food or household. Findings from research on larger industries may have better scalability and replicability potential (Parente et al., 2020; Raj et al., 2020). The insights and best practices can be adapted and applied to other industries with similar characteristics (Sanders and Wan, 2018; Kumar et al., 2020). Thus, there are more papers in normal decision-making uncertainty level.

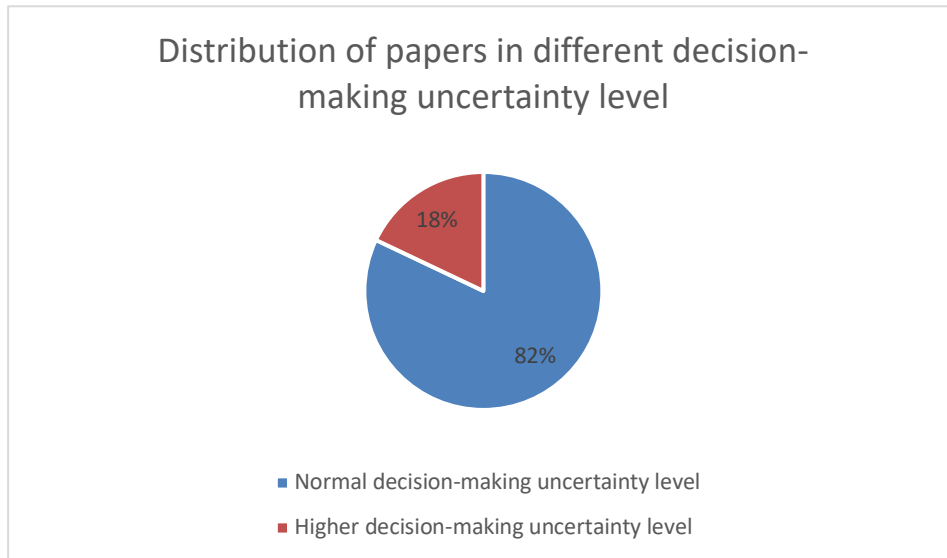
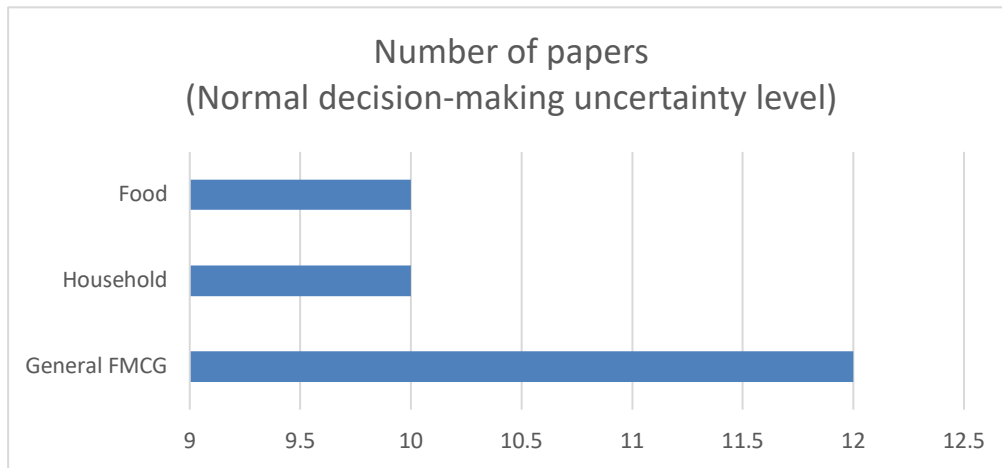


**Figure 2-4. Distribution of papers for different decision-making uncertainty levels**



**Figure**

**2-5. List of papers for different industry sectors in normal decision-making uncertainty level**

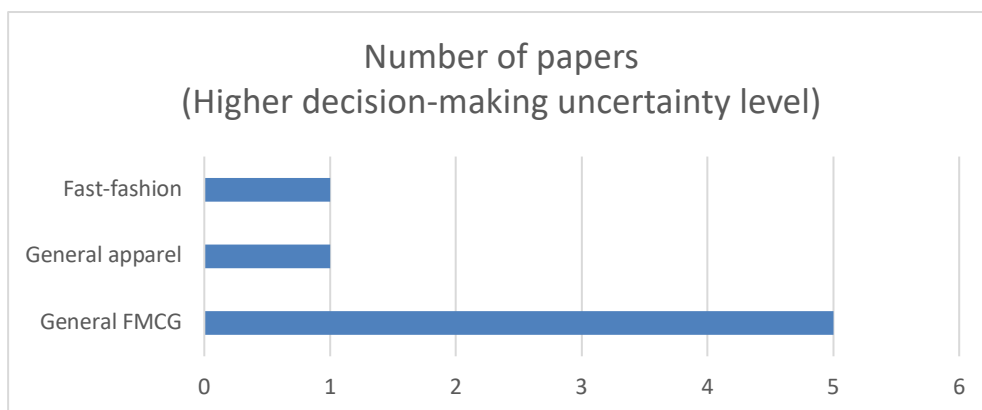


**Figure 2-6. List of papers for different industry sectors in higher decision-making uncertainty level**

The theories reported in the identified papers (Table 2-2) provide an overview of the theoretical frameworks used to study information integration. The results show that game theory is the most applied theory. Game theory comprises a set of mathematical models used to study situations in a cooperative and competitive environment where agents (e.g., individuals and organisations) interact (Myerson, 1991; Choi et al., 2020). The other two theories commonly applied are contingency theory (including IPT) and resource-based view (RBV)/knowledge-based view, with 14 papers and 10 papers, respectively.

| <b>Theory</b>                 | <b>Number of papers</b> |
|-------------------------------|-------------------------|
| Game theory                   | 23                      |
| Contingency theory/IPT        | 14                      |
| RBV/Knowledge-based view      | 10                      |
| Dynamic capability theory     | 2                       |
| Fuzzy theory                  | 2                       |
| Information theory            | 2                       |
| Network theory                | 2                       |
| Relational exchange theory    | 2                       |
| Resource dependence theory    | 2                       |
| Theory of industrial dynamics | 2                       |
| Transaction cost theory       | 2                       |
| Control theory                | 1                       |

**Table 2-2. List of theories in different research aspects**

## **2.6 Thematic Analysis**

A theme-based classification (Figure 2-7) is created to conduct the thematic analysis to analyse the sample literature and to explain the relationship between information integration and decision-making uncertainty, considering the impact of ICT.

The theme-based classification centres on the four principal clusters identified through analysis in NVivo. The classification follows IPT, viewing the supply chain as an independent system and considering the factors inside the supply chain, outside supply chain, and between supply chain stakeholders. This section focusses on the relationship between information integration and decision-making.

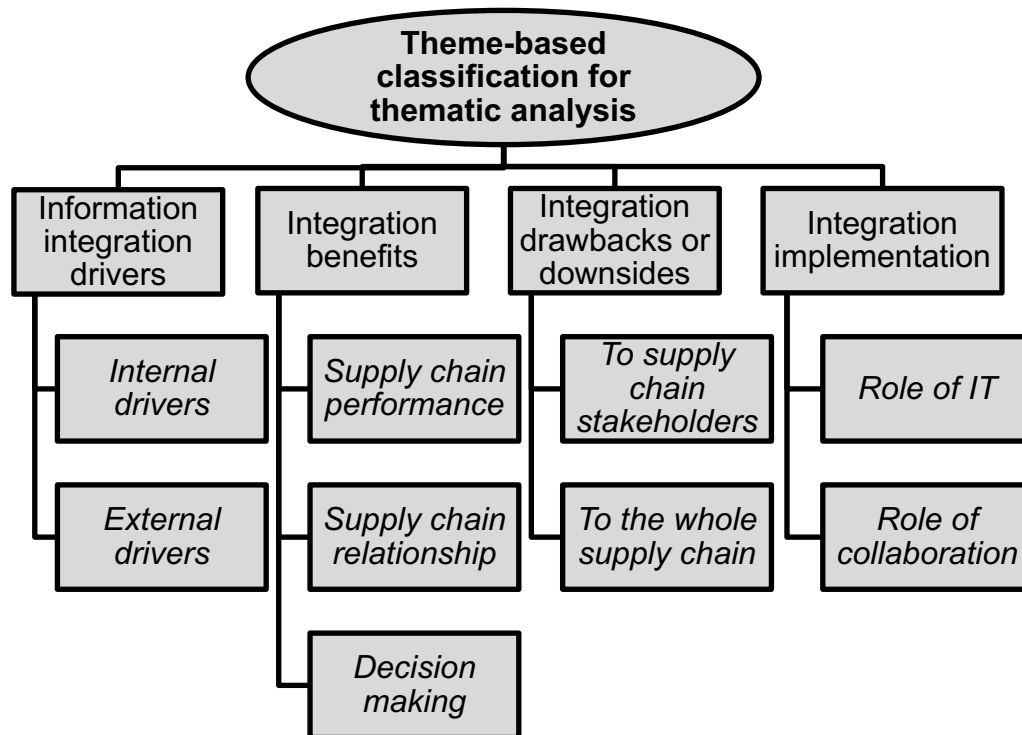


**Figure 2-7. Theme-based classification**

### **2.6.1 Information Integration Drivers Related to Decision-Making Uncertainty**

After synthesising the selected literature, the information integration drivers related to decision-making uncertainty in supply chain management can be classified as either external or internal to the supply chain.

As a critical external driver of information integration in the supply chain, environmental uncertainty impacts information integration by enhancing the willingness of supply chain stakeholders to collaborate. For example, Li and Lin (2006) find that firms in a highly uncertain environment are more likely to

communicate and cooperate with other supply chain stakeholders. Under such conditions, supply chain stakeholders struggle to acquire adequate information for decision-making without collaboration (Wong et al., 2011). Environmental uncertainty can increase a firm's need to align with other stakeholders in the upstream and downstream supply chain, and this alignment is facilitated by information integration.

The development of information technology is also recognised as a critical external driver of information integration. For instance, new and advanced ICT applications enable real-time information to be stored, analysed, and shared throughout the supply chain (Patnayakuni et al., 2006; Pramartari, 2007; Boos et al., 2013). This development provides accurate information for information integration. Chiang and Feng (2007) and Attia (2018) attest that the development of ICT supports information integration by accelerating the information transmission speed. Distinct from environmental uncertainty, the development of information technology facilitates information integration by providing technical support. Firm uncertainty may also link to this driver, as firm uncertainty relates to uncertainty caused by technology implementation (as discussed in Section 2.2). However, little evidence from the sample literature supports this perspective.

Internal drivers are identified at both the organisational and inter-organisation levels. Inter-organisational drivers between supply chain stakeholders inside the supply chain include factors that influence the relationship between supply chain stakeholders and supply chain traits. Industry uncertainty is a key internal driver of information integration. As a phenomenon caused by industry uncertainty, the bullwhip effect negatively influences cost control, inventory control, production control, and other essential business activities in the supply chain (Wangphanich et al., 2010). Firms are forced to implement information integration to mitigate the negative consequences of the bullwhip effect.

| Information integration drivers               | Supporting references                                                 |
|-----------------------------------------------|-----------------------------------------------------------------------|
| <b><i>External drivers</i></b>                |                                                                       |
| Development of information technology         | Patnayakuni et al. (2006); Salam (2017); Li et al. (2020)             |
| <b>Environmental uncertainty</b>              | Li and Lin (2006); Wong et al. (2011); Li et al. (2020)               |
| <b><i>Internal drivers</i></b>                |                                                                       |
| Inter-organisation level                      |                                                                       |
| Factors in the relationship between firms     | Perego et al. (2011); Salam (2017); Sanders and Wan (2018)            |
| The characteristics of the supply chain       | Pramatari (2007); Sabet et al. (2017); Pérez-López et al. (2019)      |
| Organisation level                            |                                                                       |
| Information technology infrastructure         | Sahin and Robinson (2005); Xu et al. (2015); Kache and Seuring (2017) |
| <b>Industry uncertainty (Bullwhip effect)</b> | Lee et al. (2000); Viswanathan et al. (2007); Niu and Zou (2017)      |

**Table 2-3. Drivers of information integration in supply chain management**

Several studies have shown that information integration improves information sharing between firms, enhancing the accuracy of demand forecasting, thus reducing the impact of the bullwhip effect (Yang et al., 2011; Mbhele and Phiri, 2014; Mbhele, 2016; Sanders and Wan, 2018; Kumar et al., 2020). These examples from the sample literature indicate that decision-making uncertainty also affects the supply chain stakeholders' willingness to adopt information integration inside the supply chain Table 2-3 lists the drivers of information integration in supply chain management identified in the sample literature, highlighting the two aspects of decision-making uncertainty identified (bolded and underlined).

### **2.6.2 The Impact of Information Integration on Supply Chain Management**

The impact of information integration divides into the two clusters (positive and negative impacts) listed in Table 2-4. Performance refers to the positive impacts of information integration on supply chain performance. Much of the identified literature (30 out of 33 papers) associates performance with supply chain management cost. Information integration allows supply chain stakeholders to increase their rate of resource utilisation, reduce their inventory, and thus reduce management costs (Stefansson, 2002; Singh and Garg, 2015; Tao et al., 2022). The impact of information integration on supply chain management cost is demonstrated by scholars both empirically and theoretically. For example, Sahin and Robinson (2005) investigated manufacturers in the metal industry and found that following an information integration strategy reduced supply chain cost by 47.58% for their sample companies. Xu et al. (2015) focussed their study on product cost, proposing a theoretical model to assess the impact of information integration implementation on improving a firm's competitiveness in the supply chain at an early stage. Many scholars (23 papers) have also attended to other factors (e.g., improving customer service and the efficiency and flexibility of supply chains).

From the relationship perspective, the literature focusses on improving communication and cooperation to create collaborative relationships between supply chain stakeholders. Information integration is proposed to promote communication between firms (Jain and Sohoni, 2015). With better communication, organisations can more easily meet each other's demands (Samaranayake and Laosirihongthong, 2016), so they become more likely to collaborate. Similarly, Boehmer et al. (2020) studied the effects of IoT-driven information integration in upstream and downstream supply chains, revealing that information integration improves partnerships between retailers and their suppliers, as well as providing further benefits to all supply chain stakeholders.

The impact of decision-making is discussed in fewer cases, with 88.9% of the identified articles (16 in 18 papers) focussing on reducing uncertainty and improving forecast accuracy. For example, it is proposed that demand uncertainty correlates with forecasting accuracy. When demand uncertainty is high, information-integration-supported forecasting is found to be more accurate than are standard forecast methods, reducing demand uncertainty in the supply chain (Acar and Atadeniz, 2015). Singh and Garg (2015) examined the inventory level and bullwhip effect in the supply chain and found that information integration benefits the whole supply chain by improving forecasting accuracy when demand fluctuates. Specifically, information integration allows supply chain stakeholders to acquire accurate real-time demand information with which they can produce precise forecasts and, hence, reduce the impact of demand fluctuation. The impact of other uncertainties, such as supply uncertainty and shipment uncertainty, are also mitigated when information integration is implemented in the supply chain (Zhang et al., 2006; Chiang and Feng, 2007; Titah et al., 2016).

In general, information integration positively influences supply chain management costs, improving the relationship between supply chain stakeholders and optimising the decision-making process by providing accurate real-time information. However, the negative impact of information integration should not be neglected. Researchers have found that high implementation costs and other difficulties hinder information integration (Stefansson, 2002; He et al., 2008; Sivadasan et al., 2013). For example, supply chain stakeholders may hesitate to adopt information integration because they are uncertain as to whether the reduction in supply chain management costs will outweigh the implementation cost (Xu et al., 2015).

Furthermore, information integration may increase the risk of security issues, revealing a firm's information to its competitors and can make a firm overly reliant on the system, ignoring potential risks (Boos et al., 2013; Chang and

Sanchez-Lloor, 2020). Notably, the extant research attends less closely to drawbacks than benefits. Only 13.9% of the sample literature (12 in 86 papers) mention drawbacks, while 86.1% (74 in 86 papers) discuss benefits.

| <b>Information</b>        |                                                                              |                                                                       |
|---------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>integration</b>        | <b>Overview</b>                                                              | <b>Supporting references</b>                                          |
| <b>impact</b>             |                                                                              |                                                                       |
| <i>Positive impact</i>    |                                                                              |                                                                       |
| Performance               | Improvement of processes, reduction of cost and higher service level         | Attia (2018); Kumar et al. (2020); Paul et al. (2022)                 |
| Relationship              | Communication method and collaboration channel                               | Li and Lin (2006); Riley et al. (2016); Boehmer et al. (2020)         |
| Decision-making           | Reduce bullwhip effect, improve information quality and forecasting accuracy | Manuj and Sahin (2011); Singh and Garg (2015); Zhang and Zhang (2020) |
| <i>Negative impact</i>    |                                                                              |                                                                       |
| Implementation difficulty | High implementation cost, unsuitable type of supply chain                    | Disney et al. (2004); He et al. (2008); Xu et al. (2015)              |
| Management risk           | Low information security; Over-reliance                                      | Jain and Sohoni (2015); Rejeb et al. (2019); Arora et al. (2022)      |

**Table 2-4. Impact of information integration on supply chain management**

### **2.6.3 Implementations of Information Integration**

The literature reports two alternative approaches to implementing information integration in supply chain management: applying advanced information technology to support new information integration methods or improving collaboration in supply chain management to enhance the extant information

integration method. Table 2-5 lists the implementations discussed in the identified literature.

The analysis of the literature on information integration implementation (44 papers in total) indicates that the implementation of Industry 4.0 ICTs crucially advances information technology applications for information integration. ICT comprises the devices, techniques, and systems that allow users to manage and share information simultaneously (Pérez-López et al., 2019). It is recognised as the foundation of information exchange at the supply chain level (Szymczak et al., 2018). Scholars in the sample literature identify the following as commonly applied ICTs for information integration in the era of Industry 4.0: the IoT (8 in 44 papers), radio frequency identification (RFID)-based sensor networks (7 in 44 papers), and cloud computing (3 in 44 papers). Other Industry 4.0 ICTs, such as the Blockchain, have not received much attention (3 in 44 papers). This analytic gap appears mainly because these advanced technologies remain under development, so few companies have adopted these technologies. The remaining papers focus on mature, well-established technologies such as electronic data interchange (EDI) and barcodes (3 papers).

The ICT application constitutes the infrastructure for information technology-based integration implementation. For example, Fatorachian and Kazemi (2021) proposed a conceptual framework to investigate the implementation of Industry 4.0 technology in the supply chain. They found that the IoT improves communication and information-sharing in supply chain management. Boos et al. (2013) investigated the advantages and disadvantages of implementing the IoT in the pharmaceutical supply chain and concluded that the IoT increases supply chain visibility and efficiency but may create an over-reliance on information integration, increasing the risk of unexpected information leakage. Other research also indicates that the application of ICTs may cause information security issues (Boos et al., 2013; Mbhele and Phiri, 2014). One

solution to this drawback may be to combine ICTs and other emerging technologies. For instance, Rejeb et al. (2019) analysed the potential of combining IoT and other emerging technologies such as blockchain technology. Their findings demonstrate that the blockchain positively influences IoT security. However, the interoperability of the blockchain and other emerging technologies and ICTs needs further investigation.

In addition, there is also evidence in the sample literature indicating that collaboration-based information integration implementation also requires the support of ICTs. For example, it has been shown that one widely adopted collaboration-based implementation tool, collaborative planning, forecasting and replenishment (CPFR), requires the application of the IoT to guarantee adequate real-time information sharing among supply chain stakeholders (Pramatari, 2007; Vijayasathy, 2010; Li and Zhang, 2015). Nevertheless, based on the sample literature, it remains too early to say categorically that ICT facilitates collaboration-based integration in the Industry 4.0 era, since these studies are theoretical or conceptual. More empirical evidence is needed to clarify the impact of ICTs on collaboration-based information integration implementation.

| Implementations      | Overview                                                                                          | Supporting references                                                      |
|----------------------|---------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Technology aspect    | Information and communication technology (RFID, M2M system, etc.)                                 | Badenhorst et al. (2013); Spiliotopoulou et al. (2016); Saha et al. (2022) |
| Collaboration aspect | Supply chain collaboration practice (e.g., collaborative forecasting, planning and replenishment) | Li et al. (2009); Yang et al. (2011); Sacristán-Díaz et al. (2018)         |

**Table 2-5. List of information integration implementations in supply chain management**

## 2.7 Discussion and Directions for Future Research

This section establishes the relational links between the key constructs of this paper, namely ICT, information integration, and decision-making uncertainty. Building on the insights identified in the thematic analysis, potential directions for future research are presented.

### 2.7.1 The Relationship between ICTs and Information Integration Implementation

Supply chain stakeholders adopt ICTs to realise information integration in the supply chain. As demonstrated in Table 2-5 and Figure 2-8, the results of the thematic analysis reveal two forms of information integration implementations: technology-based and collaboration-based.

The literature identifies that the IoT, RFID-based sensor networks, and cloud computing are the three main applications of Industry 4.0 ICTs that facilitate technology-based information integration implementation. The IoT can enable real-time collection of data from material flow, machines, production, and staff, reducing the time required for information collection and improving supply chain

efficiency (Boos et al., 2013; Ma et al., 2017; Rejeb et al., 2019). RFID-based sensor networks increase a firm's information processing capacity and provide a flexible inventory information management method (Hwang and Rho, 2014). Cloud computing demonstrates the potential to support information integration by providing a suitable storage environment for the mass of information in supply chain management (Li and Li, 2017). Thus, it can be concluded from these examples that ICT helps to provide both the technical infrastructure and the practical methods for technology-based information integration.

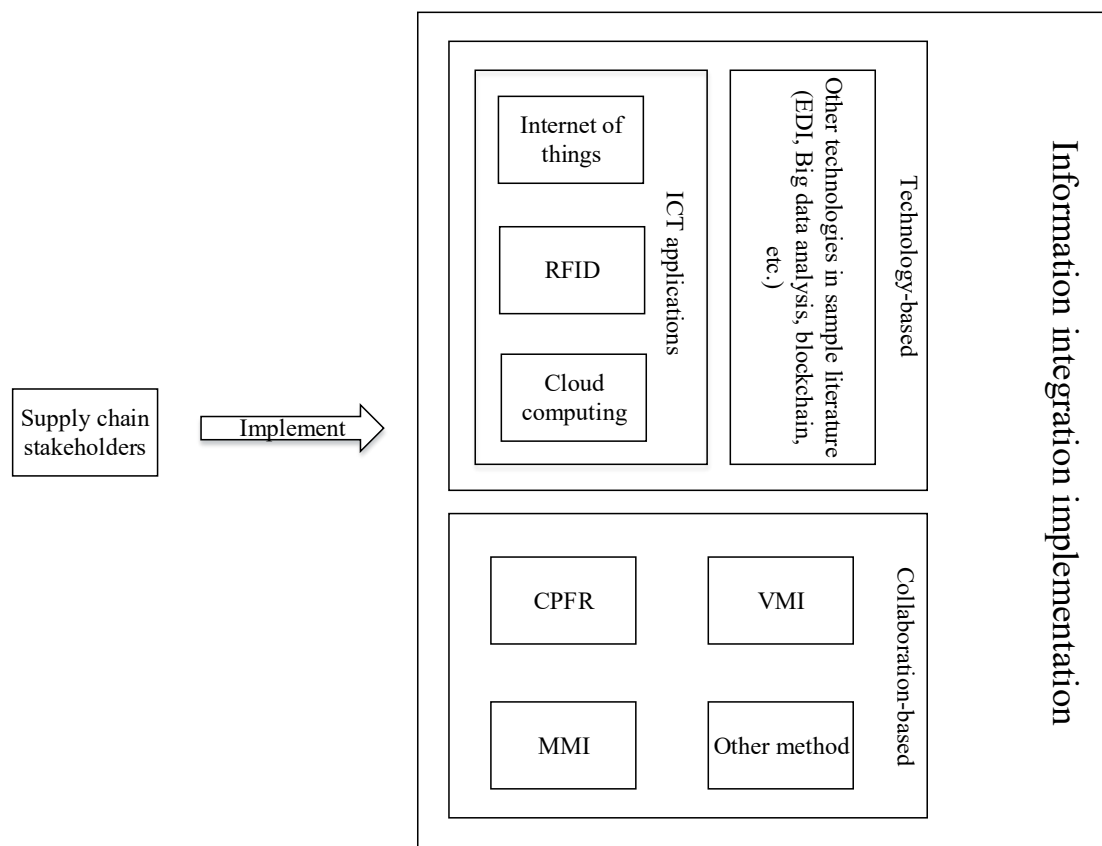


**Figure 2-8. Relationship between ICTs and information integration**

As Figure 2-8 indicates, other Industry 4.0 technologies support information integration. For instance, the only three papers in the sample literature which study big data analytics found that big data analytics improves demand forecasting accuracy (Niu and Zou, 2017; Hsu et al., 2021) and facilitates the alignment of information collected by the IoT (Rejeb et al., 2019). Consequently, information processing capability is increased, and supply chain stakeholders

can more easily apply integration and collaboration approaches (Chen et al., 2017; Kache and Seuring, 2017). Therefore, one promising direction for future study is as follows:

- *Investigate the influence of other Industry 4.0 advanced technology applications on the relationship between information integration and decision-making uncertainty.*

For example, blockchain is known to influence information transparency in supply chain management and to enhance information-sharing security between supply chain stakeholders. However, blockchain research remains nascent; how it interacts with information integration has not been fully explored (Rejeb et al., 2019; Li et al., 2020; Vu et al., 2021). A future study could investigate how blockchain influences information integration and what it brings to the relationship between information integration and decision-making uncertainty.

### **2.7.2 The Relationship between Decision-Making Uncertainty and Information Integration Implementation**

The sample literature shows that supply chain stakeholders use technology-based and collaboration-based information integration implementation methods to facilitate information management and to improve information processing capability. For instance, Titah et al. (2016) demonstrate that information integration enables firms' information-sharing processes internally and externally. According to the basic framework (Figure 2-1), an organisation's information processing capability must suit the level of uncertainty it experiences; otherwise, the misfit leads to lower performance. The relationship between decision-making uncertainty and information integration implementation can be decomposed into the following two elements (shown in Figure 2-9).

- (1) Under conditions of high uncertainty in decision-making, information integration improves information processing capability, creating fit between the information processing needs and the decision-making uncertainty experienced. This fit has a positive effect on supply chain performance. High uncertainty in decision-making complicates the process, and the demand for real-time information increases. Supply chain stakeholders will integrate information to process information and support decision-making. Consequently, the impact of decision-making uncertainty will decrease, and the whole supply chain will benefit. Wong et al.'s (2015) investigation of supply chain stakeholders under different decision-making uncertainty levels proposes that under a higher level of decision-making uncertainty, the importance of information integration increases, benefiting the performance of supply chains.
- (2) Under conditions of low decision-making uncertainty, increasing information processing capability by information integration implementation creates a mismatch with the low information-processing needs creating by low decision-making uncertainty. This mismatch diminishes supply chain performance. According to He, Marklund, and Vossen (2008) and to Titah et al. (2016), when the decision-making uncertainty is low, the decision-making process is simple, and the requirement for accurate and timely information is low. Under these circumstances, supply chain stakeholders prefer to share only the necessary information. Thus, implementing information integration increases supply chain risk and is not beneficial to the stakeholders (Titah et al. 2016).

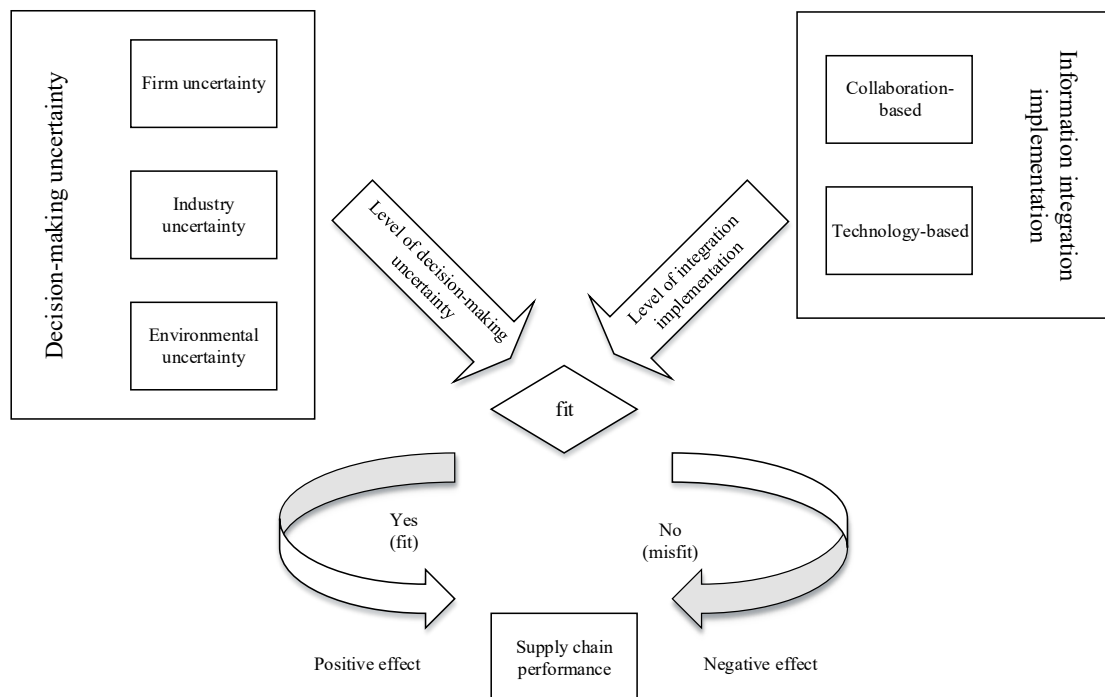


**Figure 2-9. Relationship between information integration and decision-making uncertainty (extended from Figure 1)**

As discussed in Section 2.7.2, the benefits of information integration on supply chain performance have been well explained. Evidence derived from the sample literature indicates that the relationship between information integration implementation and decision-making uncertainty can impact supply chain performance positively or negatively, depending on the fit in this relationship (He et al., 2008; Titah et al., 2016). Some scholars illustrate that the relationship between information integration implementation and decision-making uncertainty can also impact the decision-making process and the relationship between supply chain stakeholders. For instance, accurate forecasts enabled by information integration improve the decision-making process (Sanders and Wan, 2018; Wu et al., 2019), and the collaboration improved by information integration enhances the relationship between supply chain stakeholders (Xu et al., 2015; Salam, 2017). However, further clarification is needed to demonstrate the effects explicitly, yielding the following recommendation for future research:

- *Investigate the fit between information integration implementation and decision-making uncertainty and the resultant impact on supply chain performance, the relationship between supply chain stakeholders, and decision-making processes*

### **2.7.3 The Relationship between Decision-Making Uncertainty and Information Integration**

The evidence in the sample literature shows that environmental uncertainty drives supply chain stakeholders to implement information integration. For instance, Mbhele (2016) points out that environmental uncertainty frustrates the achievement of rapid responsiveness, forcing firms to adopt information integration to reduce this environmental uncertainty. One benefit of information integration implementation under environmental uncertainty is to improve supply chain performance (Khanuja and Jain, 2019). This benefit is demonstrated by Li and Lin (2006), who indicate that supply chain stakeholders are more willing to collaborate to reduce risks under conditions of high environmental uncertainty. Wong et al. (2011) also show that information integration will significantly impact product quality, delivery time, and production flexibility in the supply chain when environmental uncertainty is high. When the supply chain experiences environmental uncertainty, information integration becomes more critical to the supply chain stakeholders. Environmental uncertainty is, therefore, a critical driver of information integration.

Furthermore, the sample literature views the bullwhip effect as an internal driver of information integration. Several studies in the sample literature found the bullwhip effect to be a leading cause of forecasting inaccuracy or distortion (Ge et al., 2004; Mbhele and Phiri, 2014; Rached et al., 2016). Distorted forecasting is a typical representation of industry uncertainty (Huo et al., 2014; Ma and Ma, 2017; Snizek, 2019). By inference, industry uncertainty which leads to the bullwhip effect is another critical driver of information integration.

Figure 2-10 illustrates the relationship between decision-making uncertainty and supply chain stakeholders' willingness to participate in information integration. The sample literature reveals two key elements of decision-making uncertainty (environmental uncertainty and industry uncertainty) to be important drivers of information integration. However, as the figure shows, other key drivers of information integration, such as relationship factors (trust and commitment), do not relate directly to decision-making uncertainty. Nonetheless, these other key drivers can also raise supply chain stakeholders' willingness to implement information integration (Khanuja and Jain, 2019; Mirzabeiki and Saghiri, 2020).

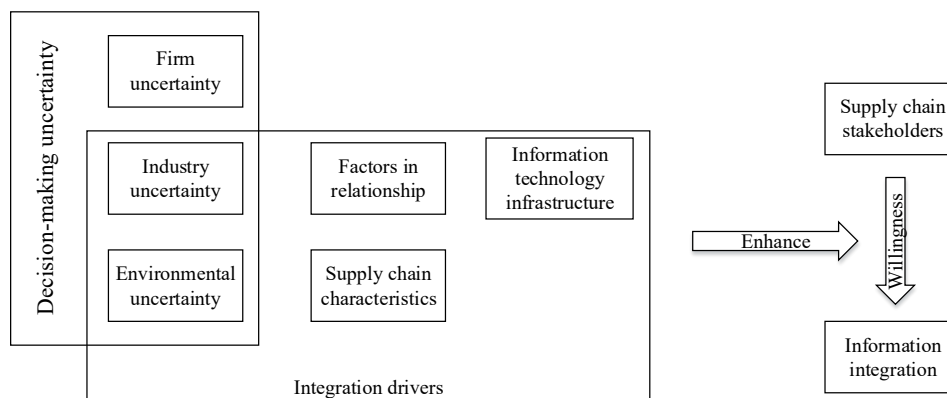


**Figure 2-10. Relationship between decision-making uncertainty and information integration**

The sample literature does not provide explicit evidence of the use of the third element of decision-making uncertainty, firm uncertainty, to improve stakeholder's willingness to participate in information integration. However, there is evidence that firm uncertainty has some effect on the development of information technology in the supply chain. For example, firms introduce new technologies into their management processes to reduce operational uncertainty (Patnayakuni et al., 2006; Chang and Sanchez-Loor, 2020; Li et al., 2020). However, to date, these discussions remain theoretical and conceptual. Further explanation and empirical evidence are required to explicitly demonstrate this link. Therefore, a worthy topic for future studies is as follows:

- *Investigate firm uncertainty as an information integration driver*

#### **2.7.4 The Theory-Based Relational Framework**

Adopting IPT, the initial theoretical framework (Figure 2-1) introduced the concept of fit into this research. The essence of the concept of fit in IPT is that the firm's information processing capacities must fit the firm's information-processing needs to enhance the firm's performance (Qrunfleh and Tarafdar, 2014; Gupta et al., 2019). This concept forms the basis of this framework. As the analysis in Section 2.7.1 identifies, three main Industry 4.0 ICT applications (IoT, RFID based sensor network, and cloud computing) facilitate technology-based information integration during information processing (Pérez-López et al., 2019; Kumar et al., 2020). Furthermore, the analysis of the impact of information integration indicates that ICT-based information integration improves information processing capabilities in supply chain management (Patnayakuni et al., 2006; Wong et al., 2015; Titah et al., 2016; Samaranayake and Laosirihongthong, 2016). Section 2.7.2's analysis proposes that two aspects of decision-making uncertainty (environmental uncertainty and industry uncertainty) are essential drivers that enhance supply chain stakeholders' willingness to implement information integration (Li and Lin, 2006; Wong et al., 2011). The analysis also indicates that decision-making uncertainty increases the information processing necessary to improve supply chain performance. Finally, the analysis and synthesis in Section 2.7.3 divides the initial framework (Figure 2-1) into three aspects – decision-making uncertainty, information integration, and supply chain performance.

Consequently, the relationship between ICT-supported information integration and decision-making uncertainty is demonstrated as follows. Information processing capability is increased by information integration, and it must fit with the information processing needs created by the level of decision-making uncertainty experienced. ICT-supported Information integration implementation

fits with a higher level of decision-making uncertainty in the supply chain. If firms cannot support information integration to parallel their decision-making uncertainty, supply chain performance will suffer.

The theory-based relational framework demonstrates the key factors that govern appropriate information integration implementation in the supply chain. However, in practice the situation can be more complicated. For instance, supply chain stakeholders are sometimes uncertain about the exact benefits of information integration because short-term profit can be hard to forecast (Lewis and Harvey, 2001). Furthermore, the drawbacks of information integration must also be considered, as difficulties in implementation and management risk limit the conditions under which implementing information integration is practical (Gunasekaran et al., 2004; Sabet, Yazdani, and De Leeuw, 2017). For instance, the unexpected information leakage caused by information integration leads to information security issues in supply chain management (Boos et al., 2013; Mbhele and Phiri, 2014). Thus, it is important to clearly explain the benefits and drawbacks of information integration for supply chain decision-makers. Accordingly, the final topic for further exploration is as follows:

- *Quantify the benefits and drawbacks of information integration implementation in the supply chain.*

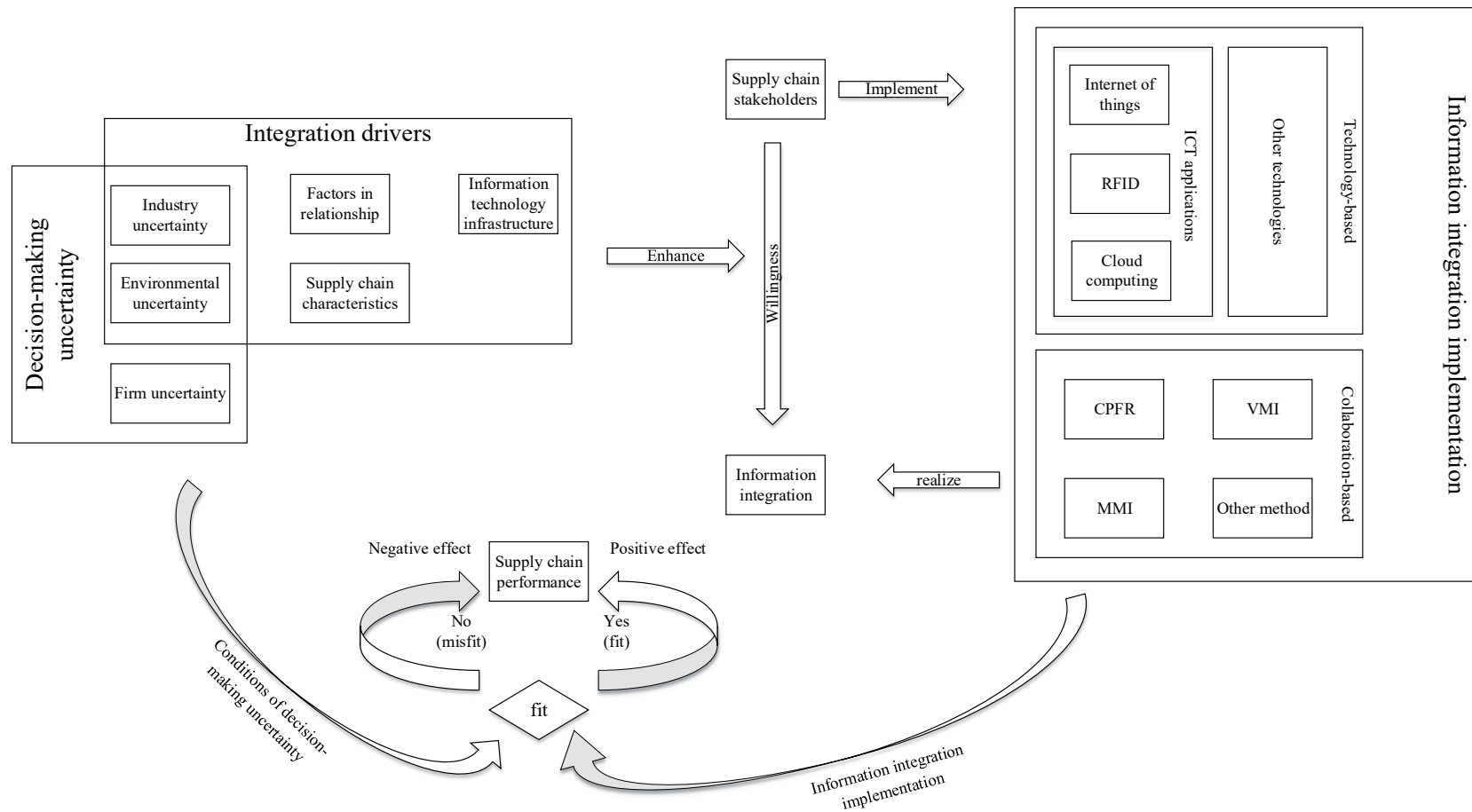


**Figure 2-11. The theory-based relational framework between information integration, decision-making uncertainty, and supply chain performance**

## 2.8 Conclusion

This paper has reviewed the extant literature to analyse the relationship between decision-making uncertainty and information integration while considering the impact of ICT. An initial theoretical framework was proposed using IPT as the theoretical lens. Following an SLR approach, the identified literature was classified into the broad themes of drivers, impacts, and information integration implementation. A theory-based relational framework was developed by synthesising the literature in the context of the initial framework. The findings demonstrate that information integration's impact on supply chain performance depends on the information processing needs that emerge from decision-making uncertainty.

This study makes several contributions. Academically, this paper systematically analyses existing knowledge on different aspects of information integration. The theory-based relational frameworks (Figure 2-8 to Figure 2-11) derived from the analysis and synthesis of the identified literature can help academics to better understand the interaction between information integration and decision-making uncertainty and the role of ICT in this relationship by providing a visual representation of the identified associations between these three elements. Furthermore, four research directions are derived from the theory-based relational framework, which can help to guide future research into the relationship between decision-making uncertainty and information integration.

In terms of managerial implications, this study's result may guide information integration. In practice, supply chain managers may be reluctant to newly implement such integration in the supply chain due to a lack of ability to forecast the short-term benefits (Lewis and Harvey, 2001). Applying the concept of fit between information integration and decision-making uncertainty, as proposed in the theoretical frameworks in this paper, will allow supply chain managers to assess their current level of decision-making uncertainty and, thus, determine the level of information integration implementation appropriate to improve the performance of their supply chain. Furthermore, the impact of specific ICT implementation on the relationship between information integration and decision-

making uncertainty can help supply chain managers to decide which specific technology is most appropriate when seeking to obtain a competitive advantage at the supply chain level.

This SLR has several limitations due to the selected methodology. Only peer-reviewed journal papers were selected for the review to ensure the papers' quality, meaning that some good works may have been missed. As only three databases are used for the review, papers not included in these databases are omitted.

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# **3 Paper 2 - IoT in Supply Chain Management: A Multiple-case Study of Its Impact on the Relationship between Information Integration and Decision-making Uncertainty**

## **Abstract**

The implementation of IoT applications is essential in modern supply chain management. This paper aims to provide a theory-based explanation for the impact of IoT applications on the measurements of information integration, decision-making uncertainty, and supply chain performance. This qualitative research uses a multiple case study approach to investigate three fast fashion supply chains in China following semi-structured interviews with 30 participants.

The analysis identifies the key factors in the alignment between information integration and decision-making uncertainty impacted by implementing IoT applications and suggests that IoT applications must be tailored to supply chain stakeholders' requirements. Driven by IoT implementation, the alignment between information integration and decision-making uncertainty positively impacts management cost, asset utilisation, response speed, operation efficiency, and flexibility. The analysis results also demonstrate the value of IoT implementation beyond data sharing and transfer. The essential variables identified in this research can benefit managers as the key performance factors for IoT implementation assessment.

Overall, the study highlights the impacts of IoT implementation on the relationship between information integration, decision-making uncertainty, and supply chain performance. The proposed framework, derived from information processing theory (IPT) and the resource-based view (RBV), is extended by the practical evidence derived from the selected cases.

**Keywords:** Internet of Things, Supply chain performance, Information integration, Decision-making uncertainty, Information processing theory

## **3.1 Introduction**

Arising from factors such as globalisation, the complexity of supply chain management creates significant decision-making uncertainty for supply chain managers (Bhatnagar and Sohal, 2005; Hult et al., 2010). More specifically, high levels of uncertainty in decision-making make it difficult for supply chain stakeholders to assess the impact of their decisions on supply chain performance (Raven et al., 1994; Wu et al., 2019). This uncertainty negatively affects inventory management by distorting demand forecasts in an unstable business environment (Gao et al., 2005; Chen et al., 2014). Therefore, when

decision-making uncertainty increases, supply chain stakeholders require more information for decision-making, and their information-processing needs increase. To satisfy the increased demand for information-processing, supply chain stakeholders try to improve their information processing capabilities, for example through a strategy of information integration that supply chain stakeholders implement to improve their information processing capabilities (Wong et al., 2015; Titah et al., 2016; Khanuja and Jain, 2019). This strategy positively influences supply chain management costs, improving the relationship between supply chain stakeholders and optimising the decision-making process by providing accurate real-time information (Acar and Atadeniz, 2015; Samaranayake and Laosirihongthong, 2016; Niu and Zou, 2017).

The Internet of Things (IoT) is a network that links physical objects together or a platform that integrates useful information into firms' information systems through the internet (Papert and Pflaum, 2017; de Vass et al., 2018; Thibaud et al., 2018). The IoT supports information integration by improving information collection. Current supply chain management studies maintain that the IoT provides an opportunity to collect sufficient information for decision-making from their partners in the supply chain. Such information helps organisations to develop new methods to improve customer response, collaborate with partners, and form a supply chain framework (Yang et al., 2013; Parry et al., 2016). Kache and Seuring (2017) identify that IoT and other advanced technologies can help firms to collect real-time information in the supply chain. Hence, IoT applications realise the use of real-time information, which provides an opportunity to optimise information integration by increasing the accuracy and efficiency of information acquisition (Zelbst et al., 2012; Parry et al., 2016; Rejeb et al., 2019).

Meanwhile, the negative impact of IoT applications on information integration should not be neglected. Some research has demonstrated that difficulties such as high implementation costs and supply chain specifications frustrate information integration (Stefansson, 2002; He et al., 2008; Sivadasan et al., 2013). The high implementation cost increases implementation difficulties, especially when they do not receive any short-term financial returns after implementing information integration (Hofmann and Rüscher, 2017; Raj et al., 2020). Furthermore, others believe that information integration may increase the risk of revealing a firm's information to its competitors or make the firm rely on the system and omit potential risks (Boos et al., 2013; Chang and Sanchez-Lloor, 2020). These challenges pose the risk of a firm losing a competitive advantage in today's high-pressure business environment. While information integration is crucial for effective supply chain management, its potential weaknesses have made organisations hesitant to adopt it. An explicit explanation is required to illustrate how the implementation of IoT applications

affects the factors impacting the relationship between information integration, decision-making uncertainty, and supply chain performance. Therefore, the research will focus on the relationship between decision-making uncertainty and the implementation of IoT applications in information integration to identify the critical factors that impacting this relationship and their resulting impact on supply chain performance. The research questions are as follows:

***RQ1. How does the implementation of IoT applications change the relationship between information integration and decision-making uncertainty?***

***RQ2. How do the changes in the relationship between information integration and decision-making uncertainty impact supply chain performance?***

This study specifically aims to investigate what factors affect the relationship between information integration and decision-making uncertainty prior to and after supply chain stakeholders adopt IoT applications in supply chain management, and how these changes impact supply chain performance. The rest of the paper now proceeds as follows. Following a critical literature review and theoretical grounding in Section 3.2, five propositions are generated. The multiple case study methodology based on semi-structured interview is then described in Section 3.3 before the findings are demonstrated in Section 3.4. Finally, the discussion, conclusion, and limitations of the paper are presented in Section 3.5.

## **3.2 Literature Review and Theoretical Grounding**

### **3.2.1 The Relationship between Information Integration and Decision-Making Uncertainty**

To analyse the alignment between information integration and decision-making uncertainty, this paper elaborates the initial theoretical framework generated from Paper 1. Based on information processing theory (IPT), the performance of a supply chain is determined by the fit between a firm's information processing capabilities and its information-processing needs (Tushman and Nadler, 1980; Daft and Lengel, 1986). Information processing needs and information processing capabilities are latent variables in the information processing model; they are non-objective and cannot be measured directly (Schoonhoven, 1981). Thus, the fit between information processing needs and information processing capability is complicated to explore directly. Drazin and Van De Ven (1985) illustrate that information processing needs and information processing capability can be identified from the features of supply chain management context and strategies. Decision-making uncertainty and information integration have been identified as essential features of supply

chain management context and strategies (Raven, McCullough, and Tansuhaj, 1994; Wong, Lai, and Cheng, 2011). For instance, when decision-making uncertainty emerges, supply chain stakeholders experience difficulty evaluating the outcome of their decisions to preserve or improve supply chain performance (Patnayakuni et al., 2006; Wu et al., 2019). Scholars indicate that the lack of information for decision-making causes this difficulty, increasing information processing needs (He et al., 2008; Titah et al., 2016). Firms adopt information integration to improve their information processing capability and to meet the increasing need for information processing. Information integration reduces the difficulty of acquiring information by improving the real-time availability of information (Seyedghorban et al., 2020) and by facilitating cooperation between supply chain stakeholders (Odważny et al., 2018). Consequently, information processing capability is increased, and supply chain stakeholders can manage decision-making uncertainty more easily (Kache and Seuring, 2017).

This paper selects decision-making uncertainty (supply chain management context) and information integration (supply chain management strategies) as surrogates for information processing needs and capacity, respectively. Based on the definition of fit (Tushman and Nadler, 1980), the consistency/alignment between decision-making uncertainty and information integration is considered another critical variable. Therefore, the initial theoretical framework generated from Paper 1 is modified, as information processing needs and capacity are paraphrased by decision-making uncertainty and information integration (Figure 3-1).

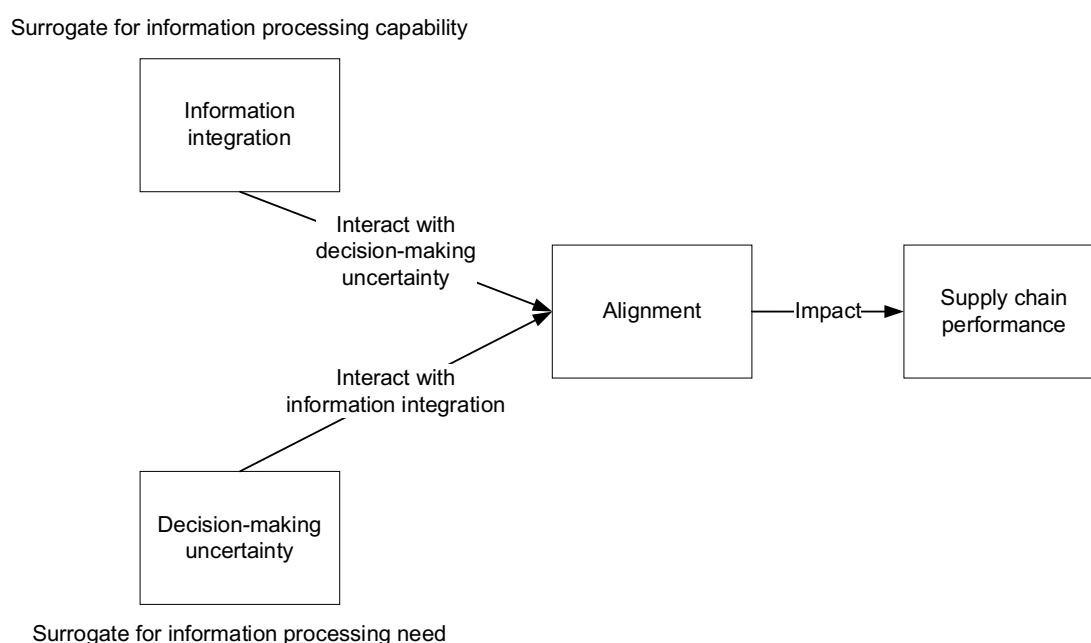


**Figure 3-1. The initial framework for the relationship between information integration and decision-making uncertainty**

### **3.2.2 The Implementation of IoT Applications for Information Integration**

In Paper 1, the theory-based relational framework confirms that the implementation of ICT supports information integration and helps to provide both the technical infrastructure and the practical methods for technology-based information integration. This IPT-based framework further develops the concept of fit proposed in contingency theory and indicates that information processing capability should fit the information processing needs and that performance is a result of that fit (Işık, 2010; Cao et al., 2015; Yuen and Thai, 2017). However, the framework does not provide details explaining how developing technologies such as Industry 4.0 IoT applications in supply chain management can support methods that firms adopt to improve their information processing capability (Premkumar et al., 2005; Zelt et al., 2019; Jia et al., 2020). A supplementary theoretical basis is needed to clarify the factors that affect information processing needs and capability in IPT.

In this research, the supply chain is studied as a whole. Paper 1 has established the IoT as a prevalent ICT in Industry 4.0. Therefore, This paper proposes that the implementation of IoT applications can significantly enhance information integration and strengthen the overall information processing capability in supply chain management. Although the evidence in Paper 1 shows that the IoT provides capabilities that may enhance operational processes, the exact impact of the IoT on information integration has not been well explained (Wade and Hullan, 2004; Kros et al., 2011). Therefore, to identify the impact of IoT applications on information integration, this paper adopts the concept of a “resource” according to the resource-based view (RBV). Rooted in management strategy literature, RBV explains how a firm can improve its performance and maintain competitiveness by acquiring and developing resources (Barney, 1991; Vijayasathya, 2010; Milana and Wu, 2012). These resources are valuable, non-substitutable, and difficult for others to copy (Zhu et al., 2014). They help the firm improve its performance via appropriate capabilities (Barney, 1991; Wade and Hullan, 2004; Song et al., 2019). A firm’s resources refer to both tangible assets (information technology infrastructure) and intangible assets (e.g., information or knowledge) (Rajaguru and Matanda, 2013), and its capabilities are regarded as the processes and routines used to deploy resources (Huo et al., 2016).

Based on the concept of a “resource” in RBV, IoT applications are regarded as indispensable resources that variously improve a firm’s ability to process information (Bhatt and Grover, 2005; Das and Teng, 2000). Turunen et al. (2018) have emphasised that the implementation of the IoT can crucially enable firms to collect real-time information, thereby enhancing their service capability. With the support of IoT applications, firms can also implement information

integration to improve their information selecting capability and supply chain performance (Peng et al., 2011). Adamson et al. (2017) indicate that IoT-based information-sharing systems help manufacturers to manage material and product flows more fluently. Chaudhuri et al. (2018) indicate that IoT-based data analytics improve decision-making processes by providing reliable forecasts. Drawing on the above scholarly work, this paper adopts the RBV as the second theoretical lens and derives the first hypothesis:

**H1.** IoTs are vital resources for supporting information collection, selection, sharing, and decision-making processes in information integration.

### **3.2.3 Key Factors of Information Integration**

Based on the findings of Paper 1 and the research aims, this section identifies the factors in information integration that shape information processing capability by considering the support of IoT applications.

Scholars connect information integration to information processing capability by illustrating its impact on information accuracy, quality, efficiency, and security (Chou et al., 2007; Hwang et al., 2019; Moser et al., 2017). Information integration-supported forecasting is proposed to be more accurate than standard forecast methods, reducing demand uncertainty in the supply chain (Acar and Atadeniz, 2015). Information integration also promotes information quality in the communication between firms (Jain and Sohoni, 2015). Moreover, information integration allows supply chain stakeholders to increase information efficiency by improving the information utilisation rate, reducing uncertainty, and refining information accuracy (Ge et al., 2004; Singh and Garg, 2015; Stefansson, 2002). However, the negative impact of information integration should not be neglected. For instance, information integration may increase the risk of revealing a firm's information to its competitors or make a firm overly reliant on the system, ignoring potential risks (Boos et al., 2013; Chang and Sanchez-Loor, 2020). Thus, information efficiency, quality, accuracy, and security can be used to measure information integration.

Information efficiency represents the effectiveness and efficiency of actions in the information-sharing process (Kolinski and Jaskolska, 2018). It can be measured by the difficulty of access to information and the time it takes to produce and retrieve information (Badenhorst et al., 2013). Information quality is defined as the information credibility (Diamantopoulos and Souchon, 1996; Low and Mohr, 2001; Menon and Varadarajan, 1992). Information quality can be measured by the information's excellence, value, and conformance to specifications or requirements, as well as its fitness for use, contribution to loss avoidance, and its meeting or exceeding its users' expectations (Li and Lin, 2006; Szymczak et al., 2018; Toften and Rustad, 2005). Information accuracy is consistent with the standard or true value of the information (Viet et al., 2018).

It can be measured by the level of error or bias and the correctness of the information compared to the value input in the supply chain (e.g., order information compared to customer demand) (Ge and Helfert, 2013; Li et al., 2017). Information security regards “the protection of information and information systems from unauthorised access, use, disclosure, disruption, modification or destruction” (Barker, 2003, p. 15). Therefore, a firm’s information security can be measured by its capability to realise such protection (Mahadevan et al., 2010).

Accordingly, the second hypothesis in this research is as follows:

**H2.** The implementation of IoT applications affects the relationship between information integration and decision-making uncertainty by influencing information accuracy, quality, efficiency, and security.

### **3.2.4 Key Factors of Decision-Making Uncertainty**

Following the seminal work of Duncan (1972), scholars categorise decision-making uncertainty into three aspects: environmental uncertainty, industry uncertainty, and firm uncertainty (Kuklinski et al., 2012; Sniazhko, 2019; Tseng and Lee, 2010). One of the research purposes is to identify the changes in the relationship between decision-making uncertainty (information processing needs) and information integration (information processing capability). Thus, this paper selects the factors that significantly impact the need for information processing as the main factors of decision-making uncertainty.

Environmental uncertainty in decision-making uncertainty refers to unexpected changes in the business environment (Rajaguru and Matanda, 2013). It relates to environmental richness and complexity (Aldrich, 1979; Dess and Beard, 1984), where the former encompasses the availability of resources and information in the business environment (Pan et al., 2018), and the latter, the diverse components of the business environment, as measured by the amount of information used to describe these components (Dess and Beard, 1984). Extant research in supply chain management also shows that environmental uncertainty influences the structure of a supply chain, such as its level of integration, the balance of power, and so forth (Achrol, Reve, and Stern, 1983; Achrol and Stern, 1988; Klein, Frazier, and Roth, 1990). The reason is that under conditions of high environmental uncertainty, supply chain stakeholders find it difficult to acquire adequate information for decision-making without collaboration (Wong et al., 2011). Therefore, the changes in the supply chain structure are added as the third factor.

As a phenomenon caused by industry uncertainty, the bullwhip effect negatively influences cost control, inventory control, production control, and other essential business activities in the supply chain (Wangphanich et al., 2010). It

is likely to cause demand forecast distortion and increase supply chain stakeholders' inventory (Chen et al., 2014; Gao et al., 2005; Plötner et al., 2013). Therefore, this paper selects the bullwhip effect as the primary measurement for industry uncertainty. It can be measured by the fluctuation ratio between the order quantity experienced by firms and the actual quantity of demand (Lee, Padmanabhan, and Whang, 1997; Ma et al., 2013; Jeong and Hong, 2019).

Firm uncertainty represents uncertainty generated in a firm's processes. The fierce competition between supply chains increases the need for information efficiency in supply chain management and leads to an "arms race" of technologies, accelerating the development of technologies in information processing (Oh and Rhee, 2008; Chang and Graham, 2012; Yu and Cao, 2020). However, when new technology appears in the supply chain, certain supply chain stakeholders may become concerned about involuntary information leakage and hesitate to apply the new technology in their firms (Qian et al., 2018; Sharma and Routroy, 2016). This hesitation delays innovation and operation in supply chain management and reduces the firm's competitiveness (Li and Lin, 2006), and weakens the users' willingness to apply technology (Autry et al., 2010; Bienstock and Royne, 2010; Lin and Lin, 2014).

As a users' degree of willingness to apply technology is defined as technology acceptance, this paper selects technology acceptance as the measurement for firm uncertainty. The third hypothesis is thus:

**H3.** The key factors of decision-making uncertainty in the relationship between decision-making uncertainty and information integration are volatility in the business environment, demand distortion in the supply chain, and technology acceptance in firms.

### **3.2.5 The Alignment between Information Integration and Decision-Making Uncertainty**

This paper selects the alignment between decision-making uncertainty and information integration to demonstrate the fit between information integration and decision-making uncertainty. This idea is adopted from the analysis result of Paper 1, which indicates that the impact of information integration on supply chain performance depends on the information processing needs created by decision-making uncertainty. This finding is also supported by a previous study in supply chain management based on IPT (Wong et al., 2015).

Further analysis of the literature indicates that the relationship between information integration and decision-making uncertainty provides financial improvements in supply chain management (He et al., 2008; Titah et al., 2016). For instance, when information integration is aligned with decision-making

uncertainty, the alignment allows supply chain stakeholders to increase their resource utilisation rate, reduce their inventory level, and reduce their management costs (Ge et al., 2004; Singh and Garg, 2015; Stefansson, 2002).

In addition, Paper 1's analysis suggests that accurate forecasts created by information integration improve the decision-making process in supply chain operations. With better communication, organisations can acquire information and communicate more quickly, making the whole supply chain network more transparent (Samaranayake and Laosirihongthong, 2016).

Based on the above, the fourth hypothesis proposed is as follows:

**H4.** The alignment between information integration and decision-making uncertainty impacts supply chain performance from the perspectives of supply chain costs and production operations.

### **3.2.6 The Revised Theory-Based Relational Framework**

According to the discussion above and combining with the findings in Paper 1, the theory-based relational framework is revised. As shown in Figure 3-2, the framework builds on the results of Paper 1 that describe the relationship between decision-making uncertainty and information integration. In addition, the framework aims to identify how IoT applications are implemented in information integration processes and to investigate the degree of alignment between information integration and decision-making uncertainty following the implementation of IoT applications. The framework uses IPT as the primary theoretical lens, identifying decision-making uncertainty as the cause of information processing needs and defining information integration as the measures firms take to improve information processing capability, with IoT being adopted to facilitate information integration. The fit between decision-making uncertainty and information integration divides into distinct focal points: the key factors of decision-making uncertainty, the key factors of information integration, and the alignment between them. To study the impact of the IoT on the fit, RBV is adopted as the supplementary theoretical lens, specifically regarding IoT infrastructure, and the information collected by IoT applications are resources to support information integration and to strengthen information processing in the supply chain.

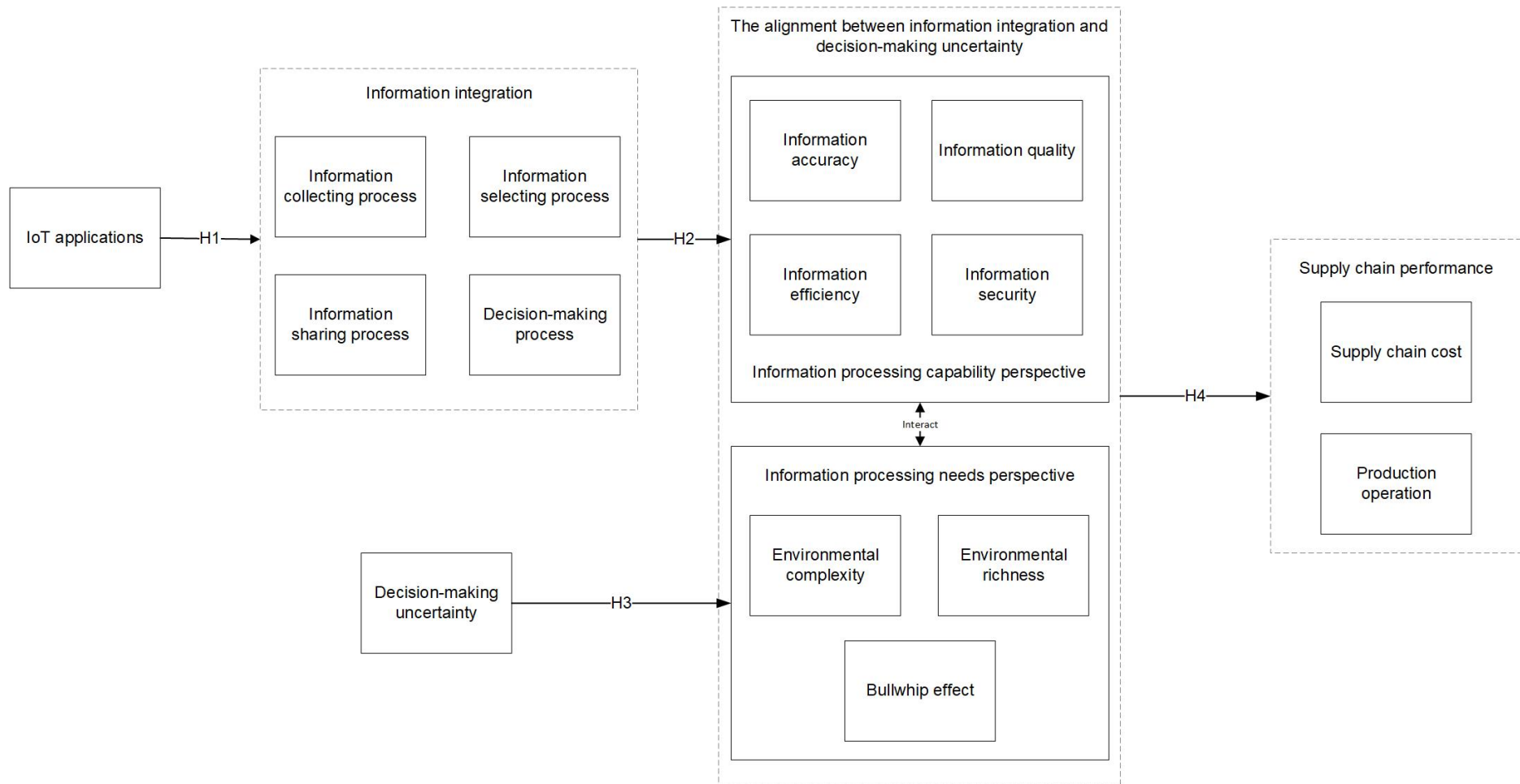


**Figure 3-2. The revised theory-based relational framework of IoT implementation in supply chain management**

### **3.3 Research Methodology**

This research uses a multiple case study to explore the relationship between IoT, decision-making uncertainty, and information integration in fast fashion supply chains. This paper aims to provide an in-depth overview of a specific phenomenon in its real-life context. In this case, the research focuses on understanding the implementation processes and outcomes of IoT applications concerning information integration and decision-making uncertainty. Case studies allow researchers to gather rich and detailed data about a specific supply chain, which can provide valuable insight into the complex and dynamic nature of the phenomenon under study (Parry et al., 2016; Zhang et al., 2017). A revised framework is developed based on IPT and RBV by considering IoTs as resources impacting information processing capability. To achieve the study objectives, deductive reasoning is appropriate since this research aims to verify the hypotheses based on theory by analysing the cases. Deductive reasoning allows researchers to initiate “a creative, iterative process of theory matching or systematic combining in an attempt to find a possible matching framework or to extend the theory used prior to this observation” (Spens and Kovács, 2006, p. 377). In addition, to the knowledge of the author, the detailed interactions between information integration and decision-making uncertainty are not predicted by the initial framework and have not been well explained in extant literature. This research concluded the interactions directly from the cases. Thus, inductive reasoning is used to generate the key interactions between information integration and decision-making uncertainty.

#### **3.3.1 Case Selection**

The fast fashion business model indicates that a fast fashion supply chain provides trendy apparel every few weeks at reasonable prices and requires a rapid response to emerging trends and frequent changes in product assortments (Caro and Martínez-de-Albéniz, 2015). Following these characteristics, three typical fast fashion supply chains in China are selected: sportswear, women’s casualwear, and men’s fashion wear. The purpose is to examine whether different product categories influence IoT applications in supply chain management. Different product categories lead to different product characteristics, influencing supply chain stakeholders’ management processes (Zimmermann, Ferreira, and Moreira, 2020). Considering that there are enterprises of different sizes and assets within a supply chain, companies of different sizes are included in the research. Scholars indicate that the adoption rate of IoT applications varies with factors such as company size and industrial sector (Stevenson and Hendry, 2007). Each case includes at least four different stakeholders from upstream to downstream in the supply chain, encompassing brand owners (retailers), apparel manufacturers, raw material

suppliers, and distributors; this criteria ensures that the selected companies form a complete supply chain, helping to provide a general overview of the implementation of IoT applications across the supply chain (shown in Figure 3-3).

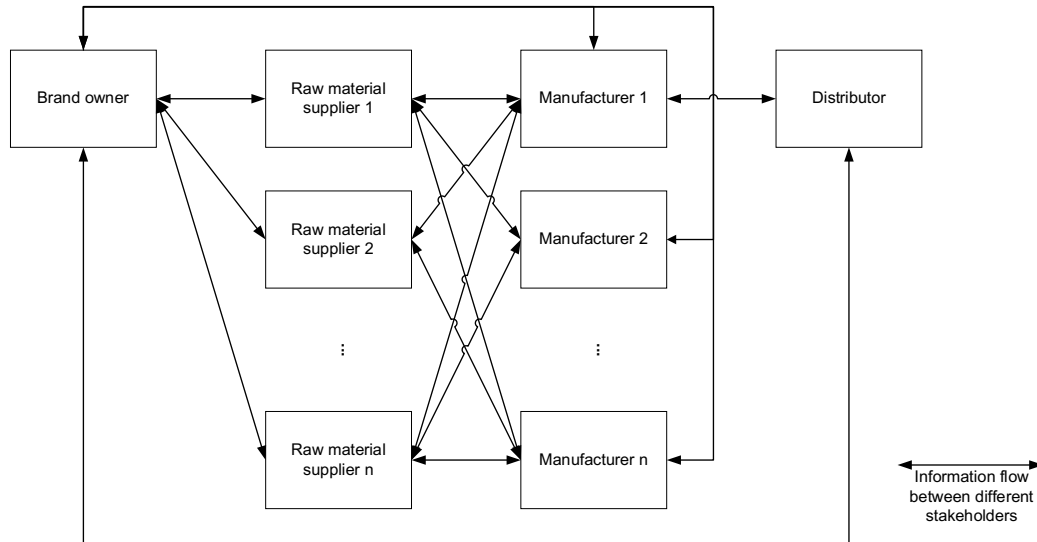


**Figure 3-3. Information flow in the selected supply chain**

The interviewees were selected based on the criteria recommended by supply chain management studies using the qualitative case study method (Seethamraju, 2014; Rymaszewska et al., 2017; Nath and Eweje, 2021). The interviewee's level of involvement and relation to supply chain management, their understanding of decision-making uncertainty, the company's demands for implementing IoT applications in their firm, and their availability and willingness to be involved in the interviewing process were used as selection criteria. The goal was to ensure the interviewees understood IoT applications, decision-making uncertainty, information integration, and supply chain performance, as well as having some experience dealing with related issues (Ingemarsdotter et al., 2020). As a result, in smaller companies, the president/CEO and senior managers in the operation were selected as interviewees. In contrast, large companies' managers related to supply chain management or technical support team directors were asked to join the meetings. Table 3-1 details the roles of interviewees in each case.

| Cases  | Organisation type       | Employees<br>(Mainland<br>China) | Registered<br>capital (Mainland<br>China) | Interviewees                                                    | Years of service<br>(current position) | Supply<br>types            | chain |
|--------|-------------------------|----------------------------------|-------------------------------------------|-----------------------------------------------------------------|----------------------------------------|----------------------------|-------|
| Case 1 | Brand owner             | 618                              | ¥ 1bn                                     | Participant 15: senior purchasing manager of a sportswear brand | 3                                      | sportswear<br>supply chain |       |
|        |                         |                                  |                                           | Participant 17: senior operations manager of a sportswear brand | 5                                      |                            |       |
|        | Raw Material Supplier 1 | 271                              | ¥ 36m                                     | Participant 21: general manager of a fabric supplier            | 4                                      |                            |       |
|        |                         |                                  |                                           | Participant 23: senior sales manager of a fabric supplier       | 5                                      |                            |       |
|        | Raw Material Supplier 2 | 671                              | \$ 50m                                    | Participant 29: senior sales manager of a trim supplier         | 3                                      |                            |       |
|        | Manufacturer 1          | 980                              | \$ 26m                                    | Participant 9: senior sales manager of an apparel manufacturer  | 4                                      |                            |       |
|        |                         |                                  |                                           | Participant 10: lean manager of an apparel manufacturer         | 3                                      |                            |       |

|        |                         |      |       |                                                                     |   |                                  |
|--------|-------------------------|------|-------|---------------------------------------------------------------------|---|----------------------------------|
|        | Manufacturer 2          | 120  | ¥ 2m  | Participant 11: operations director of an apparel manufacturer      | 4 |                                  |
|        | Distributor             | 1285 | ¥ 50m | Participant 3: operations manager of a distributor                  | 4 |                                  |
|        |                         |      |       | Participant 27: senior manager of a distributor                     | 5 |                                  |
| Case 2 | Brand owner             | 5000 | ¥ 98m | participant 13: senior sales manager of a women's casual wear brand | 5 |                                  |
|        |                         |      |       | participant 14: sales manager of a women's casual wear brand        | 6 |                                  |
|        | Raw Material Supplier 1 | 100  | ¥ 1m  | Participant 24: senior sales manager of a fabric supplier           | 4 | women's casual wear supply chain |
|        |                         |      |       | Participant 25: department director of a fabric supplier            | 5 |                                  |
|        | Raw Material Supplier 2 | 70   | ¥ 5m  | Participant 26: senior operations manager of a trim supplier        | 3 |                                  |

|        |                         |     |         |                                                                                  |                                 |
|--------|-------------------------|-----|---------|----------------------------------------------------------------------------------|---------------------------------|
|        | Manufacturer 1          | 262 | ¥ 2m    | Participant 2: sales manager of an apparel manufacturer 4                        |                                 |
|        |                         |     |         | Participant 12: development director of an apparel manufacturer 5                |                                 |
|        | Manufacturer 2          | 54  | \$ 1.6m | Participant 16: CEO of an apparel manufacturer 8                                 |                                 |
|        |                         |     |         | Participant 18: operations director of an apparel manufacturer 6                 |                                 |
|        | Distributor             | 180 | ¥ 80m   | Participant 28: operations director of a distributor 4                           |                                 |
| Case 3 | Brand owner             | 403 | ¥ 1.5bn | Participant 4: IT director of a men's fashion wear brand 5                       | men's fashion wear supply chain |
|        |                         |     |         | Participant 5: general manager's office director of a men's fashion wear brand 3 |                                 |
|        |                         |     |         | Participant 6: sales manager of a fabric supplier 6                              |                                 |
|        | Raw Material Supplier 1 | 220 | ¥ 2m    |                                                                                  |                                 |

|                         |     |       |                                                             |
|-------------------------|-----|-------|-------------------------------------------------------------|
| Raw Material Supplier 2 | 134 | ¥ 1m  | Participant 19: senior manager of a fabric supplier 4       |
|                         |     |       | Participant 22: development director of a fabric supplier 5 |
| Manufacturer 1          | 207 | ¥ 29m | Participant 1: manager of an apparel manufacturer 5         |
| Manufacturer 2          | 158 | ¥ 5m  | Participant 7: CEO of an apparel manufacturer 6             |
|                         |     |       | Participant 8: IT director of an apparel manufacturer 4     |
| Distributor             | 46  | ¥ 20m | Participant 20: department manager of a distributor 3       |
|                         |     |       | Participant 30: senior manager of a distributor 5           |

**Table 3-1. The profile of interviewees in the selected cases**

### **3.3.2 Data Collection**

The in-depth interviews based on a semi-structured guidance contributed to the primary data by generating rich data to explore a range of perspectives and to develop a holistic viewpoint ensuring that the collected data reflects participants' experiences and perspectives (Glover et al., 2014; Siddiqui et al., 2020). To answer the defined research question, the guidance was divided into three parts. The interviews began with questions on the interviewees' understanding of IoT applications and the extent to which they were involved in implementing IoT applications. Subsequently, interviewees were asked to describe why and how they (representing the different supply chain stakeholders) adopted IoT applications to support information integration in processes of information collection, selection, and sharing, as well as the results of the implementation. The second portion of the guidance focussed on the changes in the measurements of decision-making uncertainty after implementing IoT applications. In the final part of the guidance, interviewees' opinions on the alignment between information integration and decision-making uncertainty were collected. Additional detailed questions were also posed during the interviews, such as why, how, and to what extent the alignment between information integration and decision-making uncertainty impact supply chain performance. The data collection protocol was pilot tested with five interviewees from the sportswear supply chain (including different roles from upstream supplier to downstream brand owner) to ensure each question's content validity, clarity, and understandability. In total, 30 interviewees were interviewed, with an average duration of approximately 45 min. To ensure rich and detailed data was collected, the study involved multiple data sources, such as analyses of organisations' annual reports, company tours, site visits, and website materials in verifying the interviewees' answers, supporting the findings, and realising data triangulation (Glover et al., 2014; Siddiqui et al., 2020).

### **3.3.3 Data Analysis**

This study adopts a template analysis approach suitable to study the relationship between the different contexts in supply chain management research (Panda and Sahu, 2011; Matheus et al., 2017; Lusiantoro and Yates, 2021; Zubairu et al., 2021). It provides flexibility for coding structure and helps discover the 'real' internal states in the cases for theory elaboration (King, 2012). This technique allows researchers to create a priori themes in the coding process and simplify the analysis of each transcript to an iterative process of applying, modifying, and re-applying the initial template based on a subset of the data (King, 2012).

In the first stage of the coding process, this paper focussed on creating the a priori themes were generated from the revised framework (Figure 3-1). Following this framework, this paper first identified as the a priori themes (see Appendix 3-A) operational decision-making uncertainty (information processing needs), information integration (information processing capability), the alignment between decision-making uncertainty and information integration (fit between information processing needs and capability), and IoT applications (resources that improve capability).

The second stage of the coding process is to develop the initial template (see Appendix 3-B). In this stage, the extracted codes were interpreted across multiple coding waves and classified into the initial template. The a priori themes were identified as the higher-order codes. This paper then used the interview questions and transcripts as a subset of the data. During the first wave of coding, all the interview questions and the collected content in the transcripts were evaluated. The information was classified into predefined themes based on higher-order codes. Lower-order codes were added based on the analysis of interview questions and transcripts. During the second wave of coding, lower-order codes were revised, and sub-codes were added to enrich the template based on a detailed evaluation of the transcripts. Each transcript was evaluated according to the first-wave classification.

The third stage of coding was performed to conduct a keyword-based final check to ensure that all the relevant text had already been captured from all the transcripts. This procedure aimed to achieve the maximum level of replicability for the analysis.

### **3.3.4 Within-Case and Cross-Case Analyses**

Within-case and cross-case analyses (Yin, 2009) were undertaken subsequently to aggregate findings (King, 2012). In the within-case analysis, the key elements of the implementations of IoT applications for each case emerge through different information management processes, their influence on information integration and decision-making uncertainty, and the impact of the alignment between information integration and decision-making uncertainty on supply chain performance. These patterns strengthen familiarity with cases and accelerate cross-case comparison (Eisenhardt, 1989). In the cross-case analysis, the key elements identified in the three cases are compared, and the similarities and differences of the key elements in each case are listed. These key elements are tested and either confirmed or disregarded by data segments from other cases, allowing more robust theory to emerge (Eisenhardt and Graebner, 2007). Finally, this paper aggregates the analysed results, tests the propositions, and modifies the revised framework embedded in IPT and RBV.

### 3.4 Findings

The findings divide into three components. The first describes the implementation of IoT applications and their impacts on information integration. The second explains how IoT-based information integration impacts decision-making uncertainty. The third demonstrates the alignment between IoT-based information integration and decision-making uncertainty and its impact on supply chain performance.

#### 3.4.1 The Implementation of IoT Applications and Its Impact on Information Integration

All three cases follow the same steps to implement IoT applications: the implementation starts with increasing real-time information collecting in the information collecting process, uses advanced technologies (e.g., 5G) to improve information transmission through the information-selection process, and then creates connections with other supply chain stakeholders based on IoT-supported information-sharing platforms in the information-sharing process. Finally, it combines IoT applications with other technologies (big data, blockchain, etc.) to build decision-making support systems in the decision-making process. Therefore, this paper classifies the implementation of IoT applications 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). Case 1 has completed the implementation in Stage 3, and some of the stakeholders were moving to Stage 4. Case 3 had finished the implementation in Stage 2, and most of the supply chain stakeholders were in Stage 3. Case 2 was in Stage 2, and the brand owner, Raw Material Supplier 1, and Manufacturer 2 in Case 2 had finished their implementation in the information selection process, while others were about to start using IoT applications in these two processes (as shown in Table 3-2).

Stage 1, implementation in the information collection process: In the information collection process, IoT applications (e.g., radio frequency identification [RFID] and wireless sensor networks) are adopted to realise real-time information collection. By implementing IoT applications, real-time information from machines, workshops, and customers can be collected. For instance, a department manager of the distributor in Case 3 (Participant 20) indicated that

“by implementing RFID, our warehouse can promptly provide inventory level data to other departments.”

Stage 2, implementation in the information selection process: In the information selection process, IoT applications (e.g., 5G) guarantee that the collected real-

time information can be quickly transferred to the database with minimum error. As the department manager of the distributor in Case 3 (Participant 20) added,

“The data collected by RFID is sent to our database via a 5G network, which creates a high speed and low error rate internet environment for our company.”

These two stages are recognised as encompassing the infrastructure for the implementation of IoT applications in information integration. With the real-time information stored in the database, supply chain stakeholders can decide which information can be shared and how to share it with others. As the CEO of an apparel manufacturer in Case 2 (Participant 16) described,

“the factory also relies on the information from the workshop to calculate the capacity. IoT applications can help get production data directly from the machine. That is why we started the implementation of IoT applications in our information collecting process [...]. On the basis of accurate data, we can share the information of our capacity with customers and strive for more orders.”.

In Stage 3, the implementation in the information-sharing process, the information-sharing platform is set up based on IoT applications related to cloud computing, machine-to-machine systems, and so forth. The purpose of the implementation in Stage 3 is to connect with other supply chain stakeholders with the same information-sharing platform. For instance, in Case 1, the whole supply chain is in the information-sharing process, and an information-sharing platform of production status is established. The brand owner requests the raw material suppliers and manufacturers to record the production status of their orders and update it in the information-sharing platform. Based on this information, the brand owner can adjust the operation strategy in time and reduce the inventory level across the production process. One senior sales manager of an apparel manufacturer in Case 1 (Participant 9) reported,

“For example, our customers (the brand owners) now are linking our database to theirs, in order to know the production status of the whole process, [...], as long as we cooperate, the orders quantity that we received from the customer will be guaranteed [...]. There is also a reduction in the inventory level of products in process and finished products.”

Stage 4, implementation in the decision-making process: In the decision-making process, other advanced technologies are combined with IoT applications. Few companies in the selected cases were at this stage. The brand owner in Case 3 uses AI and big data analysis to help them to replenish stock for different stores. It helps realise IoT-based information integration and real-time information analysis and improves operational decision-making. As a general manager's office director of a men's fashion wears brand in Case 3 (Participant 5) illustrated,

“With the help of big data and artificial intelligence, replenishment decisions can become more reasonable, and errors can be reduced. For example, different store replenishment strategies can be implemented according to the sales volume of different styles in different stores.”

The implementation of IoT applications also has drawbacks. Despite the high implementation cost, all three cases (all the brand owners, 6/6, most of the suppliers, 6/9, most of the manufacturers, 7/10, and some of the distributors, 2/5) illustrate that implementing IoT applications across the supply chain is difficult. They must decide on the appropriate technology and application according to their situation. Thus, the IoT comprises unique resources that are difficult to replicate. For instance, a general manager of a fabric supplier in Case 1 (Participant 21) proposed,

“As in our case, IoT is not a simple software or hardware that someone can just buy and use [...], we transformed the Internet of Things application into our resources according to our needs. If we do not do this, the impact of IoT cannot be significant in our supply chain.”

Although the selected cases are in different stages of IoT implementation, certain commonalities among IoT applications' impacts on information integration can still be drawn from the data. The impacts on information integration stem principally from their implementation in information collection, selection, and sharing processes. Implementation in the decision-making process presents a potential to impact on information efficiency; however, the evidence in the selected cases is insufficient to draw a conclusion, since only one company was at Stage 4 (i.e., the brand owner in Case 3).

IoT implementation in the information collection process positively impacts information accuracy, information quality, information efficiency, and information security. The findings indicate that the real-time information from machines, materials, and products helps reduce error and bias in information, fulfil the requirement of valid data for further analysis, reduce the difficulty of accessing information, and strengthen the confidentiality of information collection. For instance, the brand owner, suppliers, and distributor in Case 1 demonstrate that RFID chips embodied in the machines, materials, in-process products, and finished products are easy to read, reduce data collection time and error, and increase the reliability of information by “letting the things talk directly”. Similar discussions have also appeared in the brand owner and Manufacturer 1 in Case 2, and the brand owner, raw material suppliers, and manufacturers in Case 3. The distributors in Cases 1 and 3 also illustrate that IoT applications in the information collection process positively impact information security. The impact on information security occurs because the information stored in the RFID tag requires bonded equipment to read and edit,

which means other devices cannot read the information in the RFID tag. They use this technology to prevent data theft.

The implementation of IoT applications in the information selection process positively impacts information efficiency and negatively impacts information security. In all three cases, the analysis results show that information accuracy and quality are not affected. For instance, although the implementation in the information selection process is just started in Case 2, the result of implementation indicates that the implementation of IoT applications in the information selection process shortens the information transfer time and reduces delay. As a senior manager of a fabric supplier in Case 2 (Participant 24) demonstrated,

“We have combined IoT applications with our existing system to upgrade the information selecting process, [...]. Now we require our suppliers with close cooperation to follow our steps. In this way, the filtered information from their production lines is directly aggregated into our system. Then, we can do some analysis.”

The negative impact of implementing IoT applications in the information selection process on information security is also mentioned in selected cases. For instance, the transport nodes in the transmission layer are vulnerable to hackers.

The findings also indicate that implementing IoT applications in the information-sharing process positively impacts information quality and efficiency but hurts information security. Especially in Case 3, IoT applications are being implemented in the information-sharing process. The implementation helps to synthesise the real-time information from information collection and selection processes, providing a platform on which to store and share information with other supply chain stakeholders. Consequently, with more real-time information stored in the platform and a better information-sharing process, supply chain stakeholders can efficiently access previously unavailable information. For instance, a sales manager of a fabric supplier in Case 3 (Participant 6) indicated,

"The information-sharing platform records the information from raw materials to final products [...], the customers (brand owners) just simply check the information they needed in the system. Moreover, the system can report the information changes immediately. Thus, a quick response can be achieved.”

The negative impact on information security comes from unexpected information leakage caused by the platform during information sharing in the supply chain. For instance, the suppliers and manufacturers have cooperated with the brand owner and implemented a cloud computing-based information-sharing system in Case 1. They found that they must attend more closely to the

screening of the shared information. Otherwise, certain trade secrets may be leaked. As an operations director of an apparel manufacturer in Case 1 (Participant 11) pointed out,

“the key point is that we must think carefully about the information we put into the platform. Much product-related information needs to be kept confidential. If the information is overly disclosed, it harms the company.”.

There is less discussion about the implementation of IoT applications in the decision-making process since the implementation of IoT applications remains underdeveloped. Only the brand owner in Case 3 had started this implementation, but only with some internal attempts, such as combining IoT applications with other technologies (big data analysis and artificial intelligence) to reduce the information processing time. Therefore, the evidence is not sufficient to demonstrate how the implementation of IoT applications in the decision-making process impacts information integration.

| Cases  | Role in the supply chain | Implementation in different processes | Impact of IoT applications on information integration |                     |                        |                      |
|--------|--------------------------|---------------------------------------|-------------------------------------------------------|---------------------|------------------------|----------------------|
|        |                          |                                       | Information accuracy                                  | Information quality | Information efficiency | Information security |
| Case 1 | Brand owner              | Information collecting                | √                                                     | √                   | √                      | -                    |
|        |                          | Information selecting                 | -                                                     | -                   | √                      | X                    |
|        |                          | Information sharing                   | -                                                     | √                   | √                      | X                    |
|        |                          | (Decision-making support)             | -                                                     | -                   | √                      | -                    |
|        | Raw Material Supplier 1  | Information collecting                | √                                                     | √                   | √                      | -                    |
|        |                          | Information selecting                 | -                                                     | -                   | √                      | -                    |
|        |                          | Information sharing                   | -                                                     | √                   | √                      | -                    |
|        |                          | (Decision-making support)             | -                                                     | -                   | √                      | -                    |
|        | Raw Material Supplier 2  | Information collecting                | √                                                     | √                   | √                      | -                    |
|        |                          | Information selecting                 | -                                                     | -                   | √                      | -                    |
|        |                          | Information sharing                   | -                                                     | √                   | √                      | -                    |
|        |                          | N/A                                   | -                                                     | -                   | -                      | -                    |
|        | Manufacturer 1           | Information collecting                | √                                                     | √                   | √                      | -                    |
|        |                          | Information selecting                 | -                                                     | -                   | √                      | -                    |
|        |                          | Information sharing                   | -                                                     | √                   | √                      | -                    |

|                         |                           |                           |   |   |   |   |
|-------------------------|---------------------------|---------------------------|---|---|---|---|
|                         |                           | (Decision-making support) | - | - | √ | - |
| Manufacturer 2          | Information collecting    | √                         | √ | √ | - |   |
|                         | Information selecting     | -                         | - | √ | X |   |
|                         | Information sharing       | -                         | - | √ | X |   |
|                         | N/A                       | -                         | - | - | - |   |
| Distributor             | Information collecting    | √                         | √ | √ | √ |   |
|                         | Information selecting     | -                         | - | √ | - |   |
|                         | Information sharing       | -                         | √ | √ | - |   |
|                         | N/A                       | -                         | - | - | - |   |
| Case 2 Brand owner      | Information collecting    | √                         | √ | √ | - |   |
|                         | Information selecting     | -                         | - | √ | - |   |
|                         | (Information sharing)     | -                         | - | √ | - |   |
|                         | (Decision-making support) | -                         | - | √ | - |   |
| Raw Material Supplier 1 | Information collecting    | √                         | √ | √ | - |   |
|                         | Information selecting     | -                         | - | √ | - |   |
|                         | (Information sharing)     | -                         | - | √ | - |   |
|                         | N/A                       | -                         | - | - | - |   |
|                         | Information collecting    | -                         | - | √ | - |   |

|                   |             |                          |   |   |   |   |
|-------------------|-------------|--------------------------|---|---|---|---|
| Raw<br>Supplier 2 | Material    | (Information selecting)  | - | - | √ | - |
|                   |             | N/A                      | - | - | - | - |
|                   |             | N/A                      | - | - | - | - |
| Manufacturer 1    |             | (Information collecting) | √ | √ | √ | - |
|                   |             | N/A                      | - | - | √ | X |
|                   |             | N/A                      | - | - | - | - |
|                   |             | N/A                      | - | - | - | - |
| Manufacturer 2    |             | Information collecting   | √ | √ | √ | - |
|                   |             | Information selecting    | - | - | √ | X |
|                   |             | (Information sharing)    | - | - | √ | X |
|                   |             | N/A                      | - | - | - | - |
| Distributor       |             | Information collecting   | √ | √ | √ | - |
|                   |             | (Information selecting)  | - | - | √ | - |
|                   |             | (Information sharing)    | - | - | - | X |
|                   |             | N/A                      | - | - | - | - |
| Case 3            | Brand owner | Information collecting   | √ | √ | √ | - |
|                   |             | Information selecting    | - | - | √ | - |
|                   |             | Information sharing      | - | √ | √ | - |

|                   |          |                           |   |   |   |   |
|-------------------|----------|---------------------------|---|---|---|---|
|                   |          | Decision-making support   | - | - | √ | - |
| Raw<br>Supplier 1 | Material | Information collecting    | √ | √ | √ | √ |
|                   |          | Information selecting     | - | - | √ | X |
|                   |          | Information sharing       | - | √ | √ | X |
|                   |          | N/A                       | - | - | - | - |
| Raw<br>Supplier 2 | Material | Information collecting    | √ | √ | √ | √ |
|                   |          | Information selecting     | - | - | √ | - |
|                   |          | Information sharing       | - | √ | √ | - |
|                   |          | (Decision-making support) | - | - | - | - |
| Manufacturer 1    |          | Information collecting    | √ | √ | √ | √ |
|                   |          | Information selecting     | - | - | √ | - |
|                   |          | Information sharing       | - | √ | √ | - |
|                   |          | N/A                       | - | - | - | - |
| Manufacturer 2    |          | Information collecting    | √ | √ | √ | - |
|                   |          | Information selecting     | - | - | √ | X |
|                   |          | Information sharing       | - | √ | √ | X |
|                   |          | (Decision-making support) | - | - | √ |   |
| Distributor       |          | Information collecting    | √ | √ | √ | √ |

|                       |   |   |   |   |
|-----------------------|---|---|---|---|
| Information selecting | - | - | √ | - |
| (Information sharing) | - | - | √ | - |
| N/A                   | - | - | - | - |

**Table 3-2. The roles of IoT applications in information integration in selected cases (√: positive impact, X: negative impact, -: no impact or impact not mentioned)**

### **3.4.2 Changes in Decision-Making Uncertainty after Implementing IoT Applications**

Environmental complexity is the main cause of issues in the selected supply chain. All three cases indicate that environmental complexity is closely related to the difficulty in supply chain management (see Table 3-3). Environmental complexity creates issues such as slowing down the responsiveness in the supply chain, tied closely to the difficulty of supply chain management. For instance, a sales department director of a manufacturer in Case 1 demonstrated that the increasing complexity in the environment is the fundamental problem that creates uncertainty in the decision-making process, influencing all supply chain stakeholders and increasing the requirement for information in the supply chain.

Environmental richness also influences supply chain management. Evidence in Case 1 shows that low environmental richness increases information processing needs by reducing access to resources or information in the business environment, creating competition between supply chain stakeholders. As the department manager of a distributor in Case 1 (Participant 27) demonstrated,

“Due to limited resources, the customer (brand owner) builds a strict evaluation system to select suppliers, manufacturers, and distributors, [...], increasing the competition within the supply chain.”

Similar findings emerge in Case 3. For instance, the manufacturers in Case 3 demonstrate that having fewer resources in the environment hinders them in obtaining enough information to assess changes in the overall business environment and make the favourable decision. The brand owners, suppliers, and manufacturers in Cases 1 and 3 also add that the difficulty caused by the low environmental richness they suffered is less than that caused by environmental complexity. The studied cases show that a resource decrease occurs gradually, providing ample time for adaptation. In contrast, a sudden increase in environmental complexity is unpredictable and beyond the managers' control. Similarly, in Case 2, the supply chain stakeholders (the brand owner, Supplier 2, Manufacturer 1, and the distributor) indicate that the low environmental richness does not cause too many issues in the supply chain, since the reduction of resources is manageable through different strategies for supply chain management.

The views of interviewees in the selected cases are very consistent on supply chain structure. Most of the interviewed supply chain stakeholders (except the brand owner in Case 3) indicate that supply chain structure has only some small influence on their operation, such as lowering communication efficiency with

others, which is only partially related to the difficulty of supply chain management.

Industry uncertainty is also highly related to the supply chain management in the selected cases. Findings in all three cases (all the brand owners, suppliers in Case 2, manufactures in Case 1 and 3, and the distributor in Case 1) indicate that the bullwhip effect caused by industry uncertainty is one of the thorniest problems in their operation. For example, a senior manager of a supplier in Case 3 (Participant 19) demonstrated that the

“Bullwhip effect will lead to the lag of information transmission and analysis and impact our inventory level; much work is needed to solve the problems caused by this lag.”

For firm uncertainty, all the supply chain stakeholders in three cases demonstrate that firm uncertainty can be overcome by the practical experience of managers or rules and regulations. Thus, its impact on supply chain management can be managed and does not increase information processing needs.

| Impact of decision-making uncertainty on supply chain management |                          |                           |                      |                        |                      |                       |
|------------------------------------------------------------------|--------------------------|---------------------------|----------------------|------------------------|----------------------|-----------------------|
| Case No.                                                         | Role in the supply chain | Environmental uncertainty |                      |                        | Industry uncertainty | Firm uncertainty      |
|                                                                  |                          | Environment complexity    | Environment richness | Supply chain structure | Bullwhip effect      | Technology acceptance |
| Case 1                                                           | Brand owner              | +++                       | ++                   | -                      | +++                  | ±                     |
|                                                                  | Raw Material Supplier 1  | +++                       | ++                   | -                      | -                    | ±                     |
|                                                                  | Raw Material Supplier 2  | ++                        | ++                   | +                      | ++                   | ±                     |
|                                                                  | Manufacturer 1           | +++                       | +                    | +                      | +++                  | ±                     |
|                                                                  | Manufacturer 2           | +++                       | +                    | -                      | +++                  | ±                     |
|                                                                  | Distributor              | ++                        | ++                   | +                      | +++                  | ±                     |
| Case 2                                                           | Brand owner              | +++                       | +                    | +                      | ++                   | ±                     |
|                                                                  | Raw Material Supplier 1  | +++                       | -                    | -                      | +++                  | ±                     |
|                                                                  | Raw Material Supplier 2  | +++                       | +                    | -                      | +++                  | ±                     |

|        |                         |     |    |    |     |   |
|--------|-------------------------|-----|----|----|-----|---|
| Case 3 | Manufacturer 1          | +++ | +  | +  | ++  | ± |
|        | Manufacturer 2          | ++  | -  | -  | +++ | ± |
|        | Distributor             | +++ | +  | +  | ++  | ± |
|        | Brand owner             | +++ | ++ | ++ | +++ | ± |
|        | Raw Material Supplier 1 | +++ | -  | -  | ++  | ± |
|        | Raw Material Supplier 2 | +++ | ++ | +  | +++ | ± |
|        | Manufacturer 1          | +++ | ++ | +  | +++ | ± |
|        | Manufacturer 2          | +++ | ++ | +  | +++ | ± |
|        | Distributor             | +++ | ++ | -  | ++  | ± |

**Table 3-3. The overview of decision-making uncertainty before implement IoT-based information integration (the issue is highly related to the difficulty in supply chain management: +++; the issue is related to the difficulty in supply chain management: ++; the issue is partially related to the difficulty in supply chain management: +; the issue is irrelevant to the difficulty in supply chain management: ±)**

The analysis shows that all the supply chain stakeholders in the select cases agree: After implementing IoT-based information integration, issues related to environmental and industry uncertainty can be resolved (see Table 3-4). Information quality is linked with environmental complexity and richness by all the three studied cases (except Supplier 1 and Manufacturer 2 in Case 2, and Supplier 1 in Case 3). For instance, the findings in Case 3 indicate that IoT-based information integration improves information quality by improving information reliability, such that it meets the users' requirements. Furthermore, IoT-based information integration enriches access to different information and records all the information in operation. Consequently, the amount of usable information in the supply chain increases. As a development director of a fabric supplier in Case 3 (Participant 22) illustrated,

"The real-time information collected by RFID guarantees the quality of information for us to analyse. Thus, the quick adjustment ability of order scheduling, the transparency of production processing, and the reasonability of sales planning are all improved. Consequently, the resistance to unexpected business environment change is improved."

Evidence from suppliers and manufacturers shows that IoT-based information integration strengthens collaboration between stakeholders in the upstream

and downstream supply chain. For instance, in Case 3, the manufacturers indicate that IoT-based information integration enhances communication methods, as with an information-sharing platform for supply chain stakeholders, and improves information efficiency in the supply chain. Finally, integration in the supply chain deepens. As a manager of an apparel manufacturer in Case 3 (Participant 1) reported,

“with the information-sharing system, our customer and us achieve win–win cooperation, and the relationship with our customer becomes more stable and long-term than in the past.”

The analysis indicates that IoT-based information integration also plays a specific role in reducing industry uncertainty. IoT-based information integration improves information accuracy, quality, and efficiency in the supply chain, mitigating the bullwhip effect in each instance. For instance, the implementation of IoT-based information integration in Case 1 mitigates the negative consequences of the bullwhip effect in the supply chain, which can optimise forecast results by using real-time information for data analysis. As a senior operation manager of the brand owner in Case 1 (Participant 17) indicated,

“First of all, forecasting efficiency will be improved [...]. The second point is that if the stakeholders in the supply chain decide to implement IoT-based information integration, the relationship between them becomes closer [...], sharing key data can be achieved, making the prediction more accurate.”

There is no evidence in the findings indicating that firm uncertainty changes after adopting IoT-based information integration. The analysis results show that technology acceptance can be improved by other management methods, such as establishing rules and regulations to ensure the implementation of IoT-based information integration.

| Cases  | Role in the supply chain | Information integration | Decision-making uncertainty |                      |                        |                 |                       |
|--------|--------------------------|-------------------------|-----------------------------|----------------------|------------------------|-----------------|-----------------------|
|        |                          |                         | Environment complexity      | Environment richness | Supply chain structure | Bullwhip effect | Technology acceptance |
|        |                          |                         | (+++)                       | (++)                 | (+)                    | (+++)           | (±)                   |
| Case 1 | Brand owner              | Information accuracy    | -                           | -                    | -                      | √               | -                     |
|        |                          | Information quality     | √                           | √                    | -                      | √               | -                     |
|        |                          | Information efficiency  | -                           | -                    | -                      | √               | -                     |
|        |                          | Information security    | -                           | -                    | -                      | -               | -                     |
|        | Raw Material Supplier 1  | Information accuracy    | -                           | -                    | -                      | √               | -                     |
|        |                          | Information quality     | √                           | √                    | -                      | √               | -                     |
|        |                          | Information efficiency  | -                           | -                    | -                      | √               | -                     |
|        |                          | Information security    | -                           | -                    | -                      | -               | -                     |
|        | Raw Material Supplier 2  | Information accuracy    | -                           | -                    | -                      | √               | -                     |
|        |                          | Information quality     | √                           | √                    | -                      | √               | -                     |
|        |                          | Information efficiency  | -                           | -                    | -                      | √               | -                     |
|        |                          | Information security    | -                           | -                    | -                      | -               | -                     |
|        | Manufacturer 1           | Information accuracy    | -                           | -                    | -                      | √               | -                     |
|        |                          | Information quality     | √                           | √                    | -                      | √               | -                     |

|                         |                        |                        |   |   |   |   |   |
|-------------------------|------------------------|------------------------|---|---|---|---|---|
|                         |                        | Information efficiency | - | - | √ | √ | - |
|                         |                        | Information security   | - | - | - | - | - |
| Manufacturer 2          | Information accuracy   | -                      | - | - | √ | - | - |
|                         | Information quality    | √                      | √ | - | √ | - | - |
|                         | Information efficiency | -                      | - | √ | √ | - | - |
|                         | Information security   | -                      | - | - | - | - | - |
| Distributor             | Information accuracy   | -                      | - | - | √ | - | - |
|                         | Information quality    | √                      | √ | - | √ | - | - |
|                         | Information efficiency | -                      | - | √ | √ | - | - |
|                         | Information security   | -                      | - | - | - | - | - |
| Case 2 Brand owner      | Information accuracy   | -                      | - | - | √ | - | - |
|                         | Information quality    | √                      | √ | - | √ | - | - |
|                         | Information efficiency | -                      | - | - | √ | - | - |
|                         | Information security   | -                      | - | - | - | - | - |
| Raw Material Supplier 1 | Information accuracy   | -                      | - | - | √ | - | - |
|                         | Information quality    | √                      | - | - | √ | - | - |
|                         | Information efficiency | -                      | - | - | √ | - | - |
|                         | Information security   | -                      | - | - | - | - | - |

|                            |                        |   |   |   |   |   |
|----------------------------|------------------------|---|---|---|---|---|
| Raw Material<br>Supplier 2 | Information accuracy   | - | - | - | √ | - |
|                            | Information quality    | √ | √ | - | √ | - |
|                            | Information efficiency | - | - | - | √ | - |
|                            | Information security   | - | - | - | - | - |
| Manufacturer 1             | Information accuracy   | - | - | - | √ | - |
|                            | Information quality    | √ | √ | - | √ | - |
|                            | Information efficiency | - | - | √ | √ | - |
|                            | Information security   | - | - | - | - | - |
| Manufacturer 2             | Information accuracy   | - | - | - | √ | - |
|                            | Information quality    | √ | - | - | √ | - |
|                            | Information efficiency | - | - | - | √ | - |
|                            | Information security   | - | - | - | - | - |
| Distributor                | Information accuracy   | - | - | - | √ | - |
|                            | Information quality    | √ | √ | - | √ | - |
|                            | Information efficiency | - | - | √ | √ | - |
|                            | Information security   | - | - | - | - | - |
| Case 3 Brand owner         | Information accuracy   | - | - | - | √ | - |
|                            | Information quality    | √ | √ | - | √ | - |

|                         |                        |                        |   |   |   |   |   |
|-------------------------|------------------------|------------------------|---|---|---|---|---|
|                         |                        | Information efficiency | - | - | √ | √ | - |
|                         |                        | Information security   | - | - | - | - | - |
| Raw Material Supplier 1 | Information accuracy   | -                      | - | - | √ | - |   |
|                         | Information quality    | √                      | - | - | √ | - |   |
|                         | Information efficiency | -                      | - | - | √ | - |   |
|                         | Information security   | -                      | - | - | - | - |   |
| Raw Material Supplier 2 | Information accuracy   | -                      | - | - | √ | - |   |
|                         | Information quality    | √                      | √ | - | √ | - |   |
|                         | Information efficiency | -                      | - | - | √ | - |   |
|                         | Information security   | -                      | - | - | - | - |   |
| Manufacturer 1          | Information accuracy   | -                      | - | - | √ | - |   |
|                         | Information quality    | √                      | √ | - | √ | - |   |
|                         | Information efficiency | -                      | - | √ | √ | - |   |
|                         | Information security   | -                      | - | - | - | - |   |
| Manufacturer 2          | Information accuracy   | -                      | - | - | √ | - |   |
|                         | Information quality    | √                      | √ | - | √ | - |   |
|                         | Information efficiency | -                      | - | √ | √ | - |   |
|                         | Information security   | -                      | - | - | - | - |   |

|             |                        |   |   |   |   |   |
|-------------|------------------------|---|---|---|---|---|
| Distributor | Information accuracy   | - | - | - | √ | - |
|             | Information quality    | √ | √ | - | √ | - |
|             | Information efficiency | - | - | √ | √ | - |
|             | Information security   | - | - | - | - | - |

**Table 3-4. The relationship between IoT-based information integration and decision-making uncertainty in selected cases (√: positive impact on decision-making uncertainty, -: no impact or impact not mentioned)**

### 3.4.3 The Alignment between IoT-based Information Integration and Decision-Making Uncertainty and Its Impact on Supply Chain Performance

*Alignment's importance.* This research identified five interactions between information integration and decision-making uncertainty, which can be concluded as the interactions between environmental complexity and information quality, environmental richness and information quality, and bullwhip effects with information quality, accuracy, and efficiency. As shown in Table 3-5, most interviewees in Cases 1 and 3 were inclined to believe the alignment is important (17 out of 20). In these two cases, the brand owners, manufacturers, and distributors all agreed that the need for information created by decision-making uncertainty must be taken seriously, and the implementation of information integration can help to fulfil the need for information created by decision-making uncertainty. According to the results, the relationship between information integration and decision-making uncertainty impacts a company's operations by establishing a more stable supply chain environment.

| Case No. | Role in the supply chain | The importance of the alignment |             |               |
|----------|--------------------------|---------------------------------|-------------|---------------|
|          |                          | Important                       | Hard to say | Not important |
| Case 1   | Brand owner              | O                               | -           | -             |
|          | Raw Material Supplier 1  | -                               | O           | -             |
|          | Raw Material Supplier 2  | O                               | -           | -             |
|          | Manufacturer 1           | O                               | -           | -             |
|          | Manufacturer 2           | O                               | -           | -             |
|          | Distributor              | O                               | -           | -             |
| Case 2   | Brand owner              | O                               | -           | -             |
|          | Raw Material Supplier 1  | -                               | O           | -             |
|          | Raw Material Supplier 2  | -                               | O           | -             |
|          | Manufacturer 1           | -                               | -           | O             |
|          | Manufacturer 2           | O                               | -           | -             |
|          | Distributor              | O                               | -           | -             |

|        |                         |   |   |   |
|--------|-------------------------|---|---|---|
| Case 3 | Brand owner             | O | - | - |
|        | Raw Material Supplier 1 | O | - | - |
|        | Raw Material Supplier 2 | - | O | - |
|        | Manufacturer 1          | O | - | - |
|        | Manufacturer 2          | O | - | - |
|        | Distributor             | O | - | - |

**Table 3-5. The importance of the alignment between information integration and decision-making uncertainty (O: mentioned by the selected cases; -: not mentioned)**

For instance, in Case 1 the whole supply chain is strongly impacted by the complexity of the business environment and the bullwhip effect (shown in Table 3-3), requiring reliable and timely information to ensure stable operation across the supply chain. Information integration is adopted as an appropriate method to improve information processing and to fulfil the requirements in the supply chain. As a lean manager of an apparel manufacturer in Case 1 (Participant 10) illustrated,

“With more and more information we collected from supply chain management processes, the uncertainty in our decision-making process is reduced, and the production process is optimized.”

Only two suppliers (Raw Material Supplier 1 in Case 1 and Raw Material Supplier 2 in Case 3) insist that a case-by-case analysis is required. Both agree that the importance of the alignment depends on the scale of the supply chain, so only in the supply chain that needs much information is the alignment vital for supply chain operation. Moreover, they indicated that the benefit of this alignment is also hard to assess.

The situation of Case 2 is complicated. Compared with other cases, the supply chain structure in Case 2 is looser, and most of the supply chain stakeholders were still not used to actively collecting and sharing information. The brand owner, one manufacturer (Manufacturer 2), and the distributor indicated that this alignment is essential, since the unmet requirement of information leads to difficulties in decision-making, and the alignment means that the need for information is fulfilled. Similar to the two suppliers in Cases 1 and 3, the suppliers in Case 2 also agree that the benefit of the alignment is challenging to assess, such that its importance is unclear. As a senior sales manager of a fabric supplier in Case 2 (Participant 24) demonstrated,

“The reality is complicated, [...], for each supply chain stakeholder, the alignment is important. For the whole supply chain, because other factors are involved, the alignment's importance is reduced.”

Manufacturer 1 in Case 2 was the only company with a contrary view in the selected cases. It is also the only company among the selected cases that had just started implementation in Stage 1. According to the manager's (Participant 2) words, the reason for late implementation is “based on the customer's (brand owner) requirement”. Participants 2 and 12 indicated that the impact of the alignment is insignificant because the demand for information remains relatively low in their circumstances, and profits are their primary concern.

*Alignment's impact on supply chain performance.* Deriving from the extant supply chain management literature, supply chain performance can be measured through financial measures (cost, profit, etc.), operational measures (order lead-time, production schedule, etc.), and customer measures (service, satisfaction, etc.) (Bhagwat and Sharma, 2007; Brewer and Speh, 2000; Balaji et al., 2018). The findings show that the positive impacts of the alignment between information integration and decision-making uncertainty divide into cost management and product operation dimensions (see Table 3-6). The alignment between IoT-based information integration and decision-making uncertainty positively impacts response speed, product flexibility, and process efficiency in production operation.

The main reason for this causal relationship is that the supply chain has become more transparent since the implementation of IoT application, such that supply chain stakeholders are better connected. For instance, an operation director of a supplier in Case 2 illustrated that the alignment improves supply chain visibility and efficiency by providing an intuitive data collection method and by increasing information accuracy. The impact on supply chain cost is illustrated in Cases 1 and 3. The supply chain stakeholders indicate that some manual work can be replaced by IoT applications, and labour costs lessen accordingly. For instance, the distributor in Case 1 uses RFID to collect information related to inventory level, guaranteeing the quality and efficiency of information collection and reducing the costs in time and labour required for manual information collection. Another improvement is in asset utilisation. Specifically, the inventory turnover ratio increases, since the forecasts are closer to customers' actual demands with the support of real-time information. As a senior purchasing manager of the brand owner in Case 1 (Participant 15) reported,

“for example, with demand information from consumers, we can make what they demand into our stock, which reduces our inventory level as well as our suppliers.”

| Case No. | Role in the supply chain | Impact on supply chain performance |                   |                |                     |                    |
|----------|--------------------------|------------------------------------|-------------------|----------------|---------------------|--------------------|
|          |                          | Total cost                         | Asset utilisation | Response speed | Product flexibility | Process efficiency |
| Case 1   | Brand owner              | O                                  | O                 | O              | O                   | O                  |
|          | Raw Material Supplier 1  | O                                  | -                 | -              | O                   | O                  |
|          | Raw Material Supplier 2  | O                                  | O                 | -              | O                   | -                  |
|          | Manufacturer 1           | -                                  | -                 | O              | O                   | O                  |
|          | Manufacturer 2           | O                                  | O                 | O              | -                   | O                  |
|          | Distributor              | O                                  | -                 | -              | O                   | O                  |
| Case 2   | Brand owner              | O                                  | O                 | -              | O                   | -                  |
|          | Raw Material Supplier 1  | -                                  | -                 | O              | O                   | O                  |
|          | Raw Material Supplier 2  | -                                  | -                 | O              | -                   | O                  |
|          | Manufacturer 1           | -                                  | -                 | -              | O                   | O                  |
|          | Manufacturer 2           | -                                  | -                 | O              | O                   | O                  |
|          | Distributor              | -                                  | -                 | -              | O                   | -                  |
| Case 3   | Brand owner              | O                                  | -                 | O              | O                   | O                  |
|          | Raw Material Supplier 1  | O                                  | O                 | -              | -                   | O                  |
|          | Raw Material Supplier 2  | O                                  | O                 | O              | O                   | -                  |
|          | Manufacturer 1           | -                                  | -                 | O              | -                   | O                  |
|          | Manufacturer 2           | O                                  | -                 | O              | -                   | O                  |
|          | Distributor              | -                                  | O                 | -              | O                   | O                  |

**Table 3-6. The alignment's impact on supply chain performance (O: mentioned by the selected cases, -: not mentioned)**

### 3.5 Discussion

The analysis presents the impact of IoT applications on the relationship between information integration and decision-making uncertainty, as well as the relationship's impact on supply chain performance, from two different views: the supply chain view (cases) and the supply chain function view (shown in Table

3-7). Based on the empirical findings, the IoT's impact on the relationship between information integration and decision-making uncertainty can be concluded from four perspectives.

First, the findings illustrate that supply chain stakeholders change IoT applications based on the actual situation and select the most appropriate technologies. In this way, IoT applications transform into the firm's resources and integrate with internal operations. This corroborates the research on RBV, demonstrating that a firm's resources are valuable, non-substitutable, and difficult for others to copy, helping the firm improve its performance via proper capabilities (Barney, 1991; Wade and Hullan, 2004; Zhu et al., 2014; Song et al., 2019). In addition, the findings confirm that the implementation of IoT applications in information integration processes depends on the level of decision-making uncertainty the supply chain stakeholders experienced. As shown in Table 6, decision-making uncertainty in Case 2 is lower than in Cases 1 and 3, especially uncertainty regarding environmental richness and supply chain structure. Consequently, the implementation progress in Case 2 (in Stage 2) lags behind that in the other two cases (in Stage 3). Similarly, the distributors in selected cases have not started to implement IoT applications in the information-sharing process. They indicate that in terms of their function in the supply chain, less information is required by their customers than must be processed internally. Thus, IoT applications in the information collection and selection process suffice to meet their current needs. The analysis indicates that the higher the level of decision-making uncertainty experienced by stakeholders in the supply chain, the higher the implementation stage they reach. The findings provide not only empirical evidence that support the theoretical framework based on IPT, but also enrich the detail of the framework by explaining the progress of implementing IoT applications in information integration.

Synthesising the above discussion, the first hypothesis is partially verified and forms the first proposition of the relationship:

Proposition 1: IoT applications are transformed into a firm's resources after implementation in the information integration processes. The higher the uncertainty the more advanced IoT adoption is likely to be.

Second, the findings also show that the implementation of IoT applications in information integration or IoT-based information integration, in other words, enhances information processing capability by improving information accuracy, quality, and efficiency in the supply chain. This paper corroborates the findings of earlier studies which suggest that IoT application constitutes the infrastructure for information integration implementation (e.g., Badenhorst et al., 2013; Spiliotopoulou et al., 2016; Rejeb et al., 2019; Fatorachian and Kazemi, 2021). The impact of IoT-based information integration on information

security is a dilemma. The extant literature mainly argues that the drawbacks of IoT applications must be carefully assessed when implemented, especially the risk to information security (Boos et al., 2013; Mbhele and Phiri, 2014). This position is taken because information systems are the foundation of modern supply chains, subject to all the risks related to supply chain management and information technology (Smith et al., 2007; Sharma and Routroy, 2016).

However, these previous studies do not clearly explain how IoT-based information integration negatively impacts information security. The findings support their discussion and specify that the implementation in the information-sharing process negatively impacts information security. For instance, the implementation in the information-sharing process is almost finished in Case 3, which shows a negative impact on information security since the information-sharing platform has higher requirements for security levels. Most of the manufacturers in all three cases are also engaged in the implementation of information-sharing processes and indicate there is a negative impact on information security due to the risk caused by higher numbers of access points to their information-sharing platform.

By contrast, the findings of this study also show that the implementation in the information collection and selection process positively impacts information security. For instance, most distributors in three cases are mainly in the information selection process. They see that the implementation positively influences information security because of the privacy of IoT applications (e.g., RFID, NB-IoT). Thus, the above discussion attests hypothesis 2 and leads to the second proposition on the relationship:

Proposition 2: IoT-based information integration positively impacts information accuracy, quality, and efficiency in information collecting, selecting, and sharing processes. However, information security is positively impacted by IoT-based information collection and selection, and negatively impacted by IoT-based information sharing.

Third, from the proposition of decision-making uncertainty, this paper finds that environmental and industry uncertainty is highly related to information processing and supply chain management. As discussed by other researchers (Raven et al., 1994; L. W. Wu et al., 2019), when decision-making uncertainty emerges, supply chain stakeholders struggle to evaluate the outcome of their decisions to preserve or improve supply chain performance. The extant literature also illustrates that environmental complexity and richness are the fundamental problems leading to unexpected changes in supply chain management: supply chain structure determines the difficulty of communication between supply chain stakeholders, and the bullwhip effect creates demand distortion and increases the pressure on inventory management (Gao et al., 2005; Plötner et al., 2013; Chen et al., 2014). In addition to confirming the

impact of environmental and industry uncertainties on supply chain management, the analysis of the supply chain stakeholders at the end of the supply chain (brand owners or distributors) also reveals that environmental richness and supply chain structure in environmental uncertainty largely do not affect the entire supply chain, especially in a supply chain in which the need for information sharing is not so urgent. This point has not been made in the extant literature. A further difference between this research and the findings of earlier studies is that this research finds that the changes in technology acceptance are not highly related to the difficulty in supply chain management. However, more evidence is required to verify this finding at the supply chain level.

Therefore, hypothesis 3 is partially verified, and the third proposition is thus:

Proposition 3: Environmental complexity and richness in environmental uncertainty and the bullwhip effect in industry uncertainty increase information processing needs in supply chain management. There is not sufficient evidence for the impact of technology acceptance in firm uncertainty on supply chain management.

Fourth, the findings indicate that IoT-based information integration increases information accuracy, quality, and efficiency in the supply chain and aligns with the environmental complexity, richness, and bullwhip effect in decision-making uncertainty. Specifically, environmental complexity interacts with information quality, environmental richness interacts with information quality, and bullwhip effects interact with information quality, accuracy, and efficiency. These interactions in the alignment between IoT-based information integration and decision-making uncertainty have not been explicitly elaborated by other researchers. Some studies in supply chain management have linked information security with decision-making uncertainty and indicate that the improvement in information security helps reduce decision-making uncertainty (e.g., Smith et al., 2007; Sharma and Routroy, 2016; Tuptuk and Hailes, 2018). However, this interaction is not as evident as other interactions such as information quality and environmental uncertainty/information efficiency and industry uncertainty. In addition, the findings support the studies in supply chain management indicating that alignment between information integration and decision-making uncertainty is important in supply chain management, creating a balance between information processing capability and information processing need and improving supply chain performance (e.g., Wong et al., 2015; Sacristán-Díaz, Garrido-Vega and Moyano-Fuentes, 2018). The findings also shows that the alignment positively impacts management cost and asset utilisation in supply chain costs, along with the response speed, product flexibility, and efficiency of product operation. Another finding worth highlighting is that the improvement in cost management emerges only after the implementation of IoT applications in an information-sharing process. This finding explains why, as other scholars indicate, supply chain stakeholders

cannot have short-term financial benefits after implementing IoT applications (Hofmann and Rüsç, 2017; Raj et al., 2020). Thus, hypothesis 4 is supported and enriched, and the final proposition on the relationship is thus:

Proposition 4: The key interactions in the alignment between IoT-based information integration and decision-making uncertainty are the interactions between environmental complexity and information quality, environmental richness and information quality, and bullwhip effects with information quality, accuracy, and efficiency. This alignment is highly related to improving management cost, asset utilisation in supply chain cost, response speed, product flexibility, and efficiency in production operations.

In addition to the above aspects, there is no evidence that different product categories and different company sizes affect the implementation of IoT applications. In all three cases, the degree of implementation is only associated with the level of decision-making uncertainty, and the cross-case analysis results confirmed that the implementation stage of information integration is associated with the level of decision-making uncertainty and did not show an exact relationship between product category and decision-making uncertainty.

| Cases                        | Implementation in different processes |                       |                     | Impact of IoT applications on information integration |                     |                        |                      |
|------------------------------|---------------------------------------|-----------------------|---------------------|-------------------------------------------------------|---------------------|------------------------|----------------------|
|                              | Information collecting                | Information selecting | Information sharing | Information accuracy                                  | Information quality | Information efficiency | Information security |
| Case 1                       | √                                     | √                     | √                   | √                                                     | √                   | √                      | -                    |
| Case 2                       | √                                     | √                     | -                   | √                                                     | √                   | √                      | -                    |
| Case 3                       | √                                     | √                     | √                   | √                                                     | √                   | √                      | X                    |
| Function in the supply chain | Implementation in different processes |                       |                     | Impact of IoT applications on information integration |                     |                        |                      |
|                              | Information collecting                | Information selecting | Information sharing | Information accuracy                                  | Information quality | Information efficiency | Information security |
| Brand owner                  | √                                     | √                     | √                   | √                                                     | √                   | √                      | -                    |
| Supplier                     | √                                     | √                     | √                   | √                                                     | √                   | √                      | -                    |
| Manufacturer                 | √                                     | √                     | √                   | √                                                     | √                   | √                      | X                    |
| Distributor                  | √                                     | √                     | -                   | √                                                     | √                   | √                      | √                    |

| Cases  | Implementation in different processes |                       |                     | Level of decision-making uncertainty in the supply chain |                      |                        |                 |                       |
|--------|---------------------------------------|-----------------------|---------------------|----------------------------------------------------------|----------------------|------------------------|-----------------|-----------------------|
|        | Information collecting                | Information selecting | Information sharing | Environment complexity                                   | Environment richness | Supply chain structure | Bullwhip effect | Technology acceptance |
| Case 1 | √                                     | √                     | √                   | +++                                                      | ++                   | +                      | +++             | ±                     |
| Case 2 | √                                     | √                     | -                   | +++                                                      | +                    | -                      | +++             | ±                     |

| Case 3                       | √                                     | √                     | √                   | +++                                       | ++                   | ++                     | +++             | ±                     |
|------------------------------|---------------------------------------|-----------------------|---------------------|-------------------------------------------|----------------------|------------------------|-----------------|-----------------------|
| Function in the supply chain | Implementation in different processes |                       |                     | Importance of decision-making uncertainty |                      |                        |                 |                       |
|                              | Information collecting                | Information selecting | Information sharing | Environment complexity                    | Environment richness | Supply chain structure | Bullwhip effect | Technology acceptance |
| Brand owner                  | √                                     | √                     | √                   | +++                                       | ++                   | +                      | +++             | ±                     |
| Supplier                     | √                                     | √                     | √                   | +++                                       | +                    | ++                     | +++             | ±                     |
| Manufacturer                 | √                                     | √                     | √                   | +++                                       | ++                   | ++                     | +++             | ±                     |
| Distributor                  | √                                     | √                     | -                   | +++                                       | ++                   | +                      | +++             | ±                     |

| Cases                        | Implementation in different processes |                       |                     | Impact on decision-making uncertainty |                      |                        |                 |
|------------------------------|---------------------------------------|-----------------------|---------------------|---------------------------------------|----------------------|------------------------|-----------------|
|                              | Information collecting                | Information selecting | Information sharing | Environment complexity                | Environment richness | Supply chain structure | Bullwhip effect |
| Case 1                       | √                                     | √                     | √                   | √                                     | √                    | -                      | √               |
| Case 2                       | √                                     | √                     | -                   | √                                     | √                    | -                      | √               |
| Case 3                       | √                                     | √                     | √                   | √                                     | √                    | √                      | √               |
| Function in the supply chain | Implementation in different processes |                       |                     | Impact on decision-making uncertainty |                      |                        |                 |
|                              | Information collecting                | Information selecting | Information sharing | Environment complexity                | Environment richness | Supply chain structure | Bullwhip effect |
| Brand owner                  | √                                     | √                     | √                   | √                                     | √                    | -                      | √               |
| Supplier                     | √                                     | √                     | √                   | √                                     | √                    | √                      | √               |

|                              |                                       |                       |                     |                                                |                   |                |                     |                    |
|------------------------------|---------------------------------------|-----------------------|---------------------|------------------------------------------------|-------------------|----------------|---------------------|--------------------|
| Manufacturer                 | √                                     | √                     | √                   | √                                              | √                 | √              | √                   |                    |
| Distributor                  | √                                     | √                     | -                   | √                                              | √                 | -              | √                   |                    |
|                              |                                       |                       |                     |                                                |                   |                |                     |                    |
| Cases                        | Implementation in different processes |                       |                     | Alignment's impact on supply chain performance |                   |                |                     |                    |
|                              | Information collecting                | Information selecting | Information sharing | Total cost                                     | Asset utilisation | Response speed | Product flexibility | Product efficiency |
| Case 1                       | √                                     | √                     | √                   | √                                              | √                 | √              | √                   | √                  |
| Case 2                       | √                                     | √                     | -                   | -                                              | -                 | √              | √                   | √                  |
| Case 3                       | √                                     | √                     | √                   | √                                              | √                 | √              | √                   | √                  |
| Function in the supply chain | Implementation in different processes |                       |                     | Alignment's impact on supply chain performance |                   |                |                     |                    |
|                              | Information collecting                | Information selecting | Information sharing | Total cost                                     | Asset utilisation | Response speed | Product flexibility | Product efficiency |
| Brand owner                  | √                                     | √                     | √                   | √                                              | -                 | √              | √                   | √                  |
| Supplier                     | √                                     | √                     | √                   | √                                              | √                 | √              | √                   | √                  |
| Manufacturer                 | √                                     | √                     | √                   | √                                              | -                 | √              | √                   | √                  |
| Distributor                  | √                                     | √                     | -                   | -                                              | √                 | √              | √                   | √                  |

**Table 3-7. The implementation of IoT applications and its impact on the different perspectives on the relationship between information integration and decision-making uncertainty (is based on the majority [60% or more] of interviewees)**

### 3.5.1 Theoretical Implications

This research makes a theoretical contribution in two respects. First, drawing from relevant IPT and RBV theories, a revised framework (Figure 3-2) was developed to implement IoT applications in supply chains, linking two research areas (information integration and decision-making uncertainty). Based on the discussion of the four propositions on the relationship between information integration and decision-making uncertainty, this paper enriched the details of the revised framework by adding the implementation processes, the interaction between different factors in information integration and decision-making uncertainty, and the aspects of supply chain performance influenced by the alignment between information integration and decision-making uncertainty (see Figure 3-4). The modified framework clarified that, for the cases, the relationship between information integration, decision-making uncertainty, and supply chain performance is not entirely consistent with the original theoretical framework and propositions. Specifically, there is no close interaction between information security and decision-making uncertainty, technology acceptance, and information integration. Thus, this study provides empirical evidence to support the discussion of several conceptual research on the implementation of IoT applications (Ben-Daya et al., 2017; Birkel and Hartmann, 2019). These studies focus on technology upgrade and improvement of existing information systems, lacking empirical evidence to identify the implementation of IoT applications from a supply perspective.

Second, the modified framework helps to identify the key factors in the relationship between IoT-based information integration and decision-making uncertainty. Specifically, this paper indicates that the improvement of information accuracy, quality, and efficiency in information integration; environmental complexity, environmental richness, and the bullwhip effect in decision-making uncertainty; and management cost, asset utilisation, response speed, product flexibility, and efficiency in supply chain performance are the key factors affected by the implementation of IoT applications. For the perspective of the alignment between information integration and decision-making uncertainty, previous research has identified an alignment between information integration and decision-making uncertainty (Cegielski et al., 2012; Fan et al., 2017). However, as an extension of the existing theory on information integration and decision-making uncertainty, this research shows that the improvement of information accuracy, quality, and efficiency in information integration interact with environmental complexity, environmental richness, and the bullwhip effect in decision-making uncertainty. Furthermore, the findings have illustrated that the interaction between IoT-based information integration and decision-making uncertainty impacts management costs, asset utilisation, response speed, product flexibility, and efficiency in supply chain performance.

In this regard, several hypotheses can be formulated and tested using quantitative methods in the future.

### **3.5.2 Managerial Implications**

Several implications for practitioners can be drawn from the findings in this study. First, the findings illustrate the potential for IoT applications beyond data sharing and data transfer. For instance, the findings indicated a potential for supply chain stakeholders to reduce supply chain management costs after implementing IoT applications in the information-sharing process. Based on this finding, supply chain managers can make more accurate predictions of implementation outcomes. Moreover, the findings propose that the implementation of IoT applications is inappropriate for certain issues caused by decision-making uncertainty. Specifically, when supply chain stakeholders perceive decision-making uncertainty, such as with the bullwhip effect and environmental complexity, the implementation of IoT applications is promising. For the issues caused by supply chain structure or firm uncertainty, the implementation of IoT applications is not the right approach. Furthermore, a step-by-step (information collecting → selecting → sharing → decision-making support) implementation process is highly recommended for supply chain managers to implement IoT applications.

Secondly, the variables of information integration, decision-making uncertainty, and supply chain performance impacted by the implementation of IoT applications are identified in the findings based on industry experts' opinions. Thus, key performance factors of IoT implementation could be created to suggest to managers what problem caused by decision-making uncertainty can be reduced and what can be achieved after the implementation of IoT applications. For instance, the bullwhip effect is among the most concerning issues in supply chain management, as it negatively influences inventory control, product operation, and other essential business activities (Wangphanich et al., 2010). With the key performance indicators (KPIs), supply chain stakeholders can learn in which implementation stage the bullwhip effect can be reduced and what impact it has on supply chain performance.

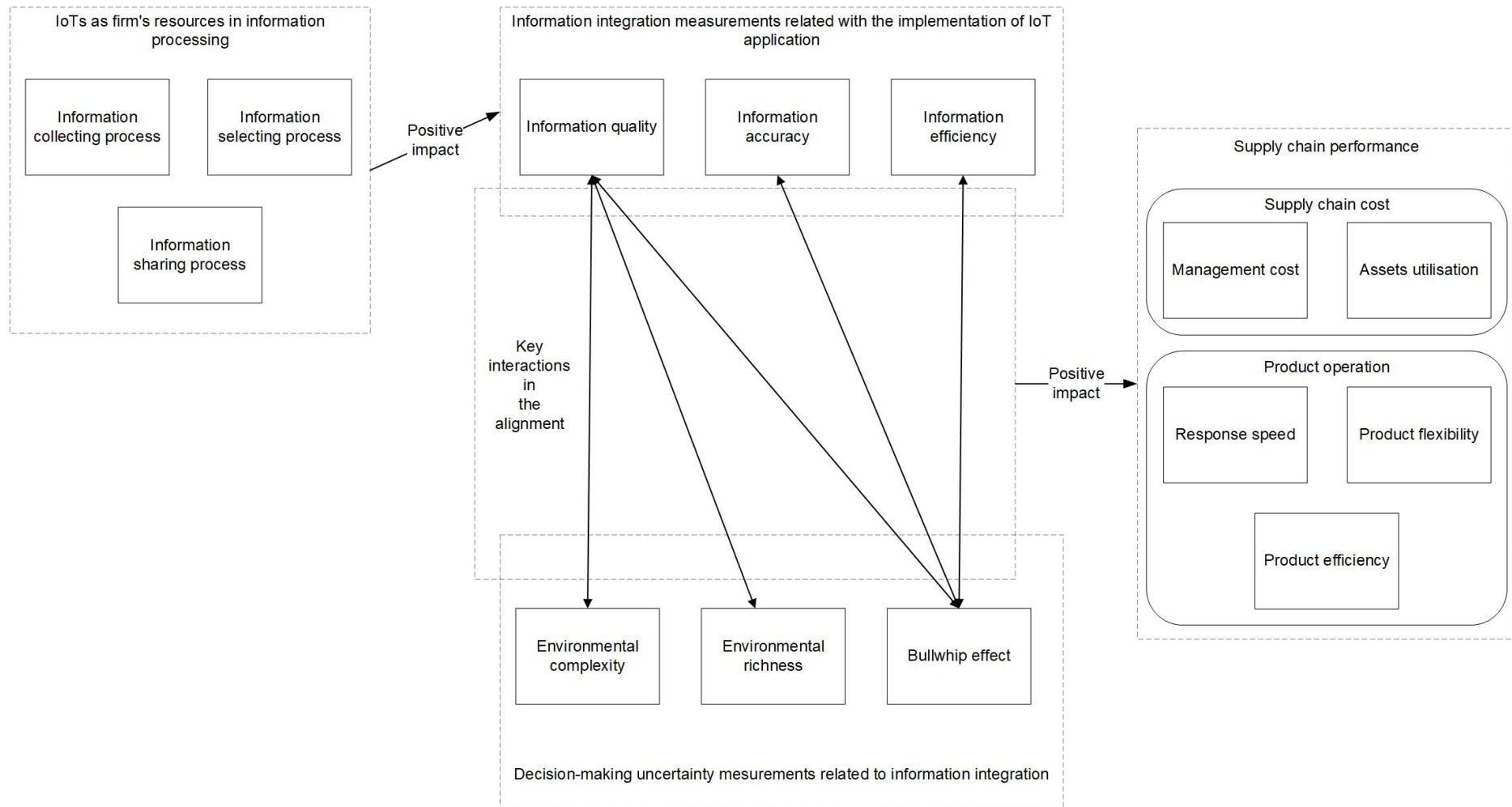


**Figure 3-4. The modified theory-based relational framework for the relationship between the implementation of IoT application, information integration, decision-making uncertainty, and supply chain performance**

### 3.6 Conclusions

In this research, this paper addressed the impacts of implementing IoT applications on the relationship between information integration and decision-making uncertainty and how this relationship impacts supply chain performance. The results establish that IoT applications are implemented in information collection, selection, and sharing alongside decision-making processes following a step-by-step implementation process based on the level of decision-making uncertainty in the supply chain. Then, information accuracy, quality, efficiency, and security are identified as four influential factors of IoT implementation on information integration. With these key factors, it is possible to map the relationship between IoT applications and information integration processes. These two findings also provide empirical evidence for extant conceptual studies on the relationship between information integration and decision-making uncertainty, and they explain the processes and impacts of implementing IoT applications in information integration from the RBV.

Distinct from the extant studies, this study's findings indicate that firm uncertainty is not highly related to the difficulties in supply chain management and, therefore, that the interaction between information integration and decision-making uncertainty occurs mostly among information accuracy, quality, efficiency, environmental complexity, richness, and the bullwhip effect. In this way, the abstract relationship between information integration and decision-making uncertainty is represented as the interaction between different factors. The explanation of these interactions provides convenience for subsequent research on the relationship between information integration and decision-making uncertainty.

The positive impact of the alignment between IoT-based information integration and decision-making uncertainty can be divided into management cost and asset utilisation in supply chain costs and product efficiency, flexibility, and response speed in production operations. These factors can be used as KPIs for supply chain managers to assess the outcomes of IoT applications. This paper also identifies that the improvement in cost management emerges only after implementing IoT applications in the information-sharing process. Thus, short-term financial benefits are difficult to achieve in the early stages of IoT applications.

This research is limited to studying the implementation of IoT applications and their impacts on the interaction between information integration and decision-making uncertainty across cases in the fast fashion supply chain. The limitation also stems from the use of multiple case studies, since the generalisability of the findings of such a case study are limited to theoretical or analytical (Yin, 2009).

Therefore, the research findings lack statistical generalisability; instead, these findings can help explain similar situations in other study contexts, such as similar supply chains in the fast fashion industry or other consumer goods industries. A large-scale survey-based study could be conducted to generalise the findings and to test the propositions statistically.

Given the study results, several promising future research directions are recommended. In this paper, key factors of information integration, decision-making uncertainty, and supply chain performance are identified based on the template analysis of practitioners' experience of implementing IoT applications. The interactions between these factors are also illustrated. Thus, a potential direction is to evaluate the degree of the interactions between the factors such as information accuracy, quality, efficiency, environmental complexity, richness, and bullwhip effect, and to assess the extent to which the interactions impact supply chain performance. Quantitative studies (e.g., large-scale surveys or simulations) are more suitable to validate the hypotheses made from these interactions. Furthermore, the findings suggest information security and technology acceptance apparently do not impact the alignment between information integration and decision-making uncertainty. However, this study focusses on the typical supply chain model in the fast fashion industry, and the situation might vary between different supply chain model. Therefore, case studies of other industry for the impact of information security and technology acceptance are highly recommended as promising research directions to study the implementation of IoT applications.

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## **4 Paper 3 - An empirical analysis of the relationship between IoT-based information integration and decision-making uncertainty**

### **Abstract**

The degree of decision-making uncertainty in the supply chain, to some extent, determines the implementation level of IoT-based information integration. Research shows that the consistency of decision-making uncertainty and information integration has a certain impact on supply chain performance. However, the extant research does not provide a comprehensive and balanced understanding of the interaction between IoT-based information integration and decision-making uncertainty and how this interaction impacts supply chain performance. This paper explains the interaction by assessing the detailed key factors in IoT-based information integration and decision-making uncertainty alongside the resulting impacts on supply chain performance. Information processing theory (IPT) is used as a theoretical lens. In the proposed theoretical framework, the key factors of decision-making uncertainty, IoT-based information integration, and supply chain performance and their interactions are assessed by a partial least squares structural equation modelling (PLS-SEM) approach. The data used for the analysis is based on the survey results collected from 275 useable responses from different supply chain stakeholders of the fast fashion industry in China. The research asserts a significant direct effect of IoT-based information integration and decision-making uncertainty on supply chain cost and production operations in supply chain performance. The alignment between IoT-based information integration and decision-making uncertainty also directly influences supply chain performance. In addition, four main interactions among key factors of IoT-based information integration and decision-making uncertainty are identified. Finally, the analysis results indicate that alignment between decision-making uncertainty and IoT-based information integration partially mediates supply chain performance. The key factors identified in this research can benefit managers and guide their development of tools and frameworks to implement IoT applications in the supply chain. In addition, the analysis results reveal the importance of the alignment between IoT-based information integration and decision-making uncertainty to improve supply chain performance, an important directive for managers. Overall, the study explains the interactions between key factors of IoT-based information integration and decision-making uncertainty. This explanation also visualised as the alignment between these two variables. By considering the partially mediating role of the alignment, a comprehensive explanation of the relationship's impacts on supply chain performance is provided. This research further contributes to the development of IPT in supply chain management. Specifically, the identified direct impact of IoT-based information integration and

decision-making uncertainty in the relationship is highlighted. Additionally, this study posits that alignment partially mediates this relationship. These findings enhance the theoretical framework based on IPT.

**Keywords:** Information integration, Decision-making uncertainty, Supply chain performance, Information processing theory, Structural equation modelling

## 4.1 Introduction

In recent years, consumers' increasing demands for personalised products have made the business environment dynamic, increasing business complexity (Azevedo and Carvalho, 2012; Moyano-Fuentes and Martínez-Jurado, 2016). Consequently, decision-making uncertainty in supply chain management has increased due to business complexity, resulting in negative impacts such as demand forecast distortion and inventory level increase on supply chain performance (Johnson and Pharr, 1997; Plötner et al., 2013; Chen et al., 2014). Recent literature on supply chain management has stressed that decision-making uncertainty increases the need for real-time information sharing among supply chain stakeholders, increasing negative effects on supply chain performance (Li et al., 2009; Mirzabeiki and Saghiri, 2020; Seyedghorban et al., 2020). Practices such as information integration have been proposed to address this requirement by enhancing information processing capabilities in the supply chain (Titah et al., 2016).

Information integration is defined as the processes (or methods) required to collect, select, and share information, along with the infrastructure necessary for these activities (Lee et al., 2000; Danese et al., 2013; Büyüközkan and Göçer, 2018). It is essential to improve supply chain performance in many industries (Nakandala et al., 2017). The extant research on information integration indicates that IoT applications support information integration by providing technical infrastructure for information collection and practical mechanisms for supply chain collaboration (Hwang and Rho, 2014). For example, IoT-based information integration will positively impact product quality, delivery time, and production flexibility in the supply chain under high environmental uncertainty (Wong et al., 2011). Furthermore, the real-time information sharing facilitated by IoT-based information integration mitigates the bullwhip effect generated by industry uncertainty (Rached et al., 2016). It also improves the accuracy of forecasts and enhances collaboration between supply chain stakeholders (Niu and Zou, 2017).

In practice, nevertheless, the situation is more complicated. Certain research has demonstrated that high implementation costs and specific supply chain types make IoT-based information integration difficult to realise (Stefansson, 2002; He et al., 2008; Sivadasan et al., 2013). Specifically, IoT-based information integration increases the amount of required real-time information

and accelerates information collection and sharing speed, requiring upgrades to existing hardware and software to analyse and process the information (Zdravković et al., 2018; Ingemarsdotter et al., 2020). Consequently, the implementation costs of IoT-based information integration increase (Lee and Lee, 2015; Lampropoulos et al., 2019). Furthermore, although many scholars link the impact of IoT-based information integration to decision-making uncertainty, the extant research focusses primarily on specific perspectives of decision-making uncertainty (e.g., environmental uncertainty). Their findings have not provided a comprehensive and balanced understanding of the alignment between IoT-based information integration and decision-making uncertainty (Seyedghorban et al., 2020). Scholars also indicate that supply chain stakeholders generally do not achieve short-term outcomes after implementing IoT-based information integration, making the impacts of IoT-based information integration on decision-making uncertainty difficult to assess (Boos et al., 2013; Hofmann and Rüscher, 2017; Chang and Sanchez-Loor, 2020). Therefore, this research will evaluate the alignment between IoT-based information integration and different aspects of decision-making uncertainty and identify the impact of this alignment on different perspectives of supply chain performance. The research questions are thus:

***RQ1. What are the interactions between IoT-based information integration and decision-making uncertainty?***

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

The rest of the paper is structured as follows. Section 4.2 details the theoretical background and the hypotheses' development. Section 4.3 illustrates the research methodology based on a survey and PLS-SEM modelling. Section 4.4 then introduces the results of hypotheses testing and mediation analyses. Section 4.5 presents the discussion, followed by the conclusions, theoretical and managerial implications, and research limitations in Section 4.6.

## **4.2 Theoretical Background and Hypotheses Development**

Paper 2 indicates that IoT-based information integration and decision-making uncertainty impact supply chain performance. Several factors of IoT-based information integration, decision-making uncertainty, and supply chain performance are also identified. To maintain continuity with Papers 1 and 2, Paper 3 adopts information processing theory (IPT) as the theoretical basis on which to study the alignment between IoT-based information integration and decision-making uncertainty.

Specifically, this paper links decision-making uncertainty with information processing needs. The findings in Paper 2 verify that decision-making uncertainty is an important feature of the supply chain management context. Under conditions of high decision-making uncertainty, the outcome of supply chain stakeholders' decisions on supply chain performance is difficult to evaluate, frustrating supply chain management (Patnayakuni et al., 2006; Wong et al., 2011; Wu et al., 2019). These difficulties increase information processing needs in the supply chain (He et al., 2008; Titah et al., 2016). As discussed in Paper 1, IoT-based information integration is a supply chain management strategy firms use to improve information processing capabilities. Paper 2's findings confirm the impact of IoT-based information integration on information collection, selection, and sharing processes. Similar findings in the extant literature indicate that such integration reduces the difficulty of acquiring real-time information (Seyedghorban et al., 2020) and facilitates information sharing in the supply chain (Odważny et al., 2018). 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 alignment between decision-making uncertainty and IoT-based information integration (see Figure 4-1).

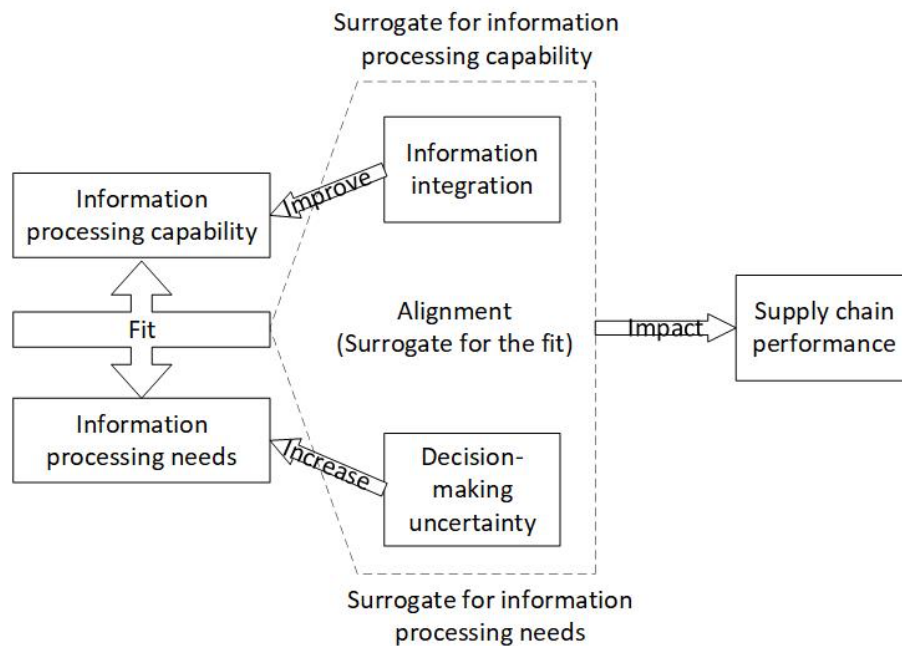


**Figure 4-1.** The initial framework of the alignment between IoT-based information integration and decision-making uncertainty (Titah et al., 2016; Odważny et al., 2018).

#### **4.2.1 The Impact of Decision-Making Uncertainty on Information Processing Needs**

The analysis result of Paper 2 provides empirical evidence illustrating that environmental uncertainty and industry uncertainty are the leading causes of increasing information processing needs in a highly inconstant business environment, providing empirical evidence for former studies (Chen et al., 2014; Moyano-Fuentes and Martínez-Jurado, 2016). Environmental uncertainty increases environmental complexity and reduces environmental richness in the supply chain. Paper 2 has proposed that environmental complexity is the diversity of environmental components (elements of the natural environment, social factors, etc.) with which supply chain stakeholders interact, characterised by information processing requirements in the supply chain (Aldrich, 1979; Castrogiovanni, 1991). The findings in Paper 2 affirm that under high environmental complexity, supply chain stakeholders require more information to support their decision-making processes (Rajaguru and Matanda, 2013). Environmental richness is linked to the availability of resources and information in the environment (Pan et al., 2018). The findings in Paper 2 demonstrate that under high environmental uncertainty, the available resources for firms operating within an environment are limited, and environmental richness diminishes (Raven et al., 1994). Scholars have also indicated that environmental uncertainty strongly impacts supply chain performance, especially when environmental uncertainty is high (Eker and Eker, 2019; James and George, 2018). This indication is also verified in Paper 2. The bullwhip effect, a typical phenomenon caused by industry uncertainty, causes the distortion of customer demand in the supply chain (Zhou and Benton, 2007; Lee et al., 2016; Belhadi et al., 2021). Scholars have demonstrated that the bullwhip effect negatively influences supply chain performance by increasing inventory levels and management costs (Lee et al., 1997; Gowda and Subramanya, 2017). To reduce the bullwhip effect, firms must get more information from customers, the market, and other supply chain stakeholders (Ma and Ma, 2017). The above arguments lead to the following hypothesis:

***Hypothesis 1.*** Increasing decision-making uncertainty (environmental and industry uncertainties) negatively impacts supply chain performance.

#### **4.2.2 The Impact of IoT-Based Information Integration on the Information Processing Capability**

Paper 2's analysis illustrates that IoT-based information integration improves information processing capability through information accuracy, quality, and efficiency, as does evidence from the literature. For example, radio frequency identification (RFID)-based sensor networks improve information accuracy in the information collection process and bring real-time inventory information to supply chain stakeholders, increasing the firm's information processing capacity and providing a flexible inventory information management method (Hwang and Rho, 2014). Cloud computing demonstrates the potential to support information integration by providing a suitable storage environment for the massive amount of information and accelerating the information-sharing process in supply chain management (Li and Li, 2017). IoT-based information integration can enable real-time data collection from material flow, machines, production, and staff to reduce the time required for information collection and to improve supply chain efficiency (Ma et al., 2017; Rejeb et al., 2019). IoT-based information integration is tightly linked to supply chain performance. Tao and Qi (2019) have studied IoT implementation in manufacturers, indicating that IoT-driven information integration improves production scheduling. Similarly, de Vass et al. (2018) emphasise that IoT-based information integration helps a firm improve its performance and gain a competitive advantage in supply chain management.

These IoT technologies are also identified in Paper 2, classified into four implementation stages. Corresponding hypothesis can now be tested:

***Hypothesis 2.*** The implementation of IoT-based information integration has a positive impact on supply chain performance.

#### **4.2.3 The Alignment Between IoT-based Information Integration and Decision-Making Uncertainty**

Following the discussions in Sections 4.2.1 and 4.2.2, the basic factors in IoT-based information integration and decision-making uncertainty are created: information accuracy, quality, efficiency for information integration and environment complexity, richness and bullwhip effect for decision-making uncertainty. The following discussion focuses on finalising the relationship between information integration and decision-making uncertainty through the key factors and the resulting impact on supply chain performance.

The importance of the alignment between decision-making uncertainty and IoT-based information integration is well discussed in Paper 2. The information processing theorists also indicate that the fit between information processing needs and information processing capability demonstrates the extent to which

the information processing needs can be fulfilled by information processing capability (Galbraith, 1973; Tushman and Nadler, 1980). It is essential to balance the fit between information processing needs and information processing capability to maintain stable operations and to improve supply chain performance (Fan et al., 2017; Jain et al., 2017; Gupta et al., 2019). The current paper proposes that decision-making uncertainty creates information processing needs and that IoT-based information integration improves information processing capabilities. Previous studies have demonstrated that supply chain stakeholders' capacity to process received and shared information is critical to deal with decision-making uncertainties (Yuen and Thai, 2017). Combining the above arguments with the findings in Paper 2, this paper expects prevalent IoT-based information integration and decision-making uncertainty to align:

**Hypothesis 3-1.** The implementation of IoT-based information integration shows high consistency with the level of decision-making uncertainty.

Previous literature suggests that improving information accuracy increases the value of information and makes information more applicable to stakeholders, leading to accurate forecasting of customer demand and reducing the bullwhip effect (Li et al., 2017; Viet et al., 2018). Similarly, improving information quality reduces the error in the information, increasing the stability and accuracy of the customer demand forecasting process and mitigating the impact of the bullwhip effect in supply chain management (Chatfield et al., 2004; Ge and Helfert, 2013; Lu et al., 2017). The improvement of information efficiency also reduces the bullwhip effect. It realises real-time information sharing and reduces processing time in information collection (Badenhorst et al., 2013; Kolinski and Jaskolska, 2018). Paper 2 empirically supports this research and indicates that information security is not deeply impacted by IoT applications.

Moreover, the improvement of information quality reduces the level of environmental uncertainty in supply chain management. Evidence in the extant literature indicates that the optimisation of information adequacy and credibility leads to the improvement of the utilisation of external resources and the fulfilment of information requirements in supply chain management (Li and Lin, 2006; Nagarajan et al., 2013). Consequently, the issues caused by high environmental complexity and low richness are resolved (Cegielski et al., 2012; Lusiantoro et al., 2018). Paper 2 draws a similar conclusion. Based on this discussion, this paper proposes the following hypotheses:

**Hypothesis 3-2.** The improvement of information accuracy aligns with the diversity of environmental components in the supply chain.

**Hypothesis 3-3.** The improvement of information accuracy aligns with the availability of information or resources in the environment.

**Hypothesis 3-4.** The improvement of information accuracy aligns with the reduction of demand fluctuation in the supply chain.

**Hypothesis 3-5.** The improvement of information quality aligns with the diversity of environmental components in the supply chain.

**Hypothesis 3-6.** The improvement of information quality aligns with the availability of information or resources in the environment.

**Hypothesis 3-7.** The improvement of information quality aligns with the reduction of demand fluctuation in the supply chain.

**Hypothesis 3-8.** The improvement of information efficiency aligns with the diversity of environmental components in the supply chain.

**Hypothesis 3-9.** The improvement of information efficiency aligns with the availability of information or resources in the environment.

**Hypothesis 3-10.** The improvement of information efficiency aligns with the reduction of demand fluctuation in the supply chain.

#### **4.2.4 The Impact of the Alignment between IoT-Based Information Integration and Decision-Making Uncertainty on Supply Chain Performance**

The case study results demonstrate that the alignment between IoT-based information integration and decision-making uncertainty positively impacts supply chain performance by reducing supply chain costs and by improving production operations.

Paper 2 concludes that this alignment positively impacts management cost and asset utilisation in supply chain cost management. Scholars also indicate that this alignment allows supply chain stakeholders to increase resource utilisation and reduce management costs (Stefansson, 2002; Ge et al., 2004; Singh and Garg, 2015). In addition, the alignment promotes the use of technology, results in the replacement of manual work by machines, and accordingly reduces labour costs (Durugbo et al., 2014; Zhou et al., 2015; Fatorachian and Kazemi, 2021). Evidence in literature also demonstrates that the alignment can also strengthen collaboration among supply chain stakeholders, affecting the payment process and accelerating the capital flow (Chakuu et al., 2019). Consequently, it positively affects working capital. Having synthesised the findings of extant studies on supply chain cost management with the analysis results of Paper 2, this paper advances the following hypothesis:

**Hypothesis 4.** The alignment between IoT-based information integration and decision-making uncertainty positively impacts supply chain cost in supply chain performance.

**Hypothesis 4-1.** The alignment between IoT-based information integration and decision-making uncertainty positively impacts management costs in supply chain cost management.

**Hypothesis 4-2.** The alignment between IoT-based information integration and decision-making uncertainty positively impacts working capital in supply chain cost management.

**Hypothesis 4-3.** The alignment between IoT-based information integration and decision-making uncertainty positively impacts asset utilisation in supply chain cost management.

Furthermore, Paper 2's findings show that the alignment between IoT-based information integration and operational decision-making uncertainty positively impacts response speed, process efficiency, and production flexibility in product operation. The main reason for this impact is that the alignment improves supply chain transparency and demand forecasting accuracy, such that supply chain stakeholders are better connected (Birkel and Hartmann, 2019). For instance, collaboration enhances the interaction between supply chain stakeholders, improves communication among supply chain stakeholders, and accelerates response speeds in the supply chain by providing quicker access to information (Núñez-Merino et al., 2020). The alignment also improves the decision-making process in production, reducing production process time and increasing scheduling flexibility (Xu et al., 2015; Salam, 2017). Further, better communication among supply chain stakeholders also increases forecast accuracy and reduces product defects (Sanders and Wan, 2018). Therefore, this paper considers product quality to be another importation factor. Having synthesised the findings of extant studies on production operations, this paper advances the following hypothesis:

**Hypothesis 5.** The alignment between IoT-based information integration and decision-making uncertainty positively impacts production operations in supply chain performance.

**Hypothesis 5-1.** The alignment between IoT-based information integration and decision-making uncertainty positively impacts response speed in production operations.

**Hypothesis 5-2.** The alignment between IoT-based information integration and decision-making uncertainty positively impacts production flexibility in production operations.

**Hypothesis 5-3.** The alignment between IoT-based information integration and decision-making uncertainty positively impacts product quality in production operations.

**Hypothesis 5-4.** The alignment between IoT-based information integration and decision-making uncertainty positively impacts process efficiency in production operations.

The hypothesised research model suggests the interaction between IoT-based information integration and decision-making uncertainty and the impact of their relationship on supply chain performance (shown in

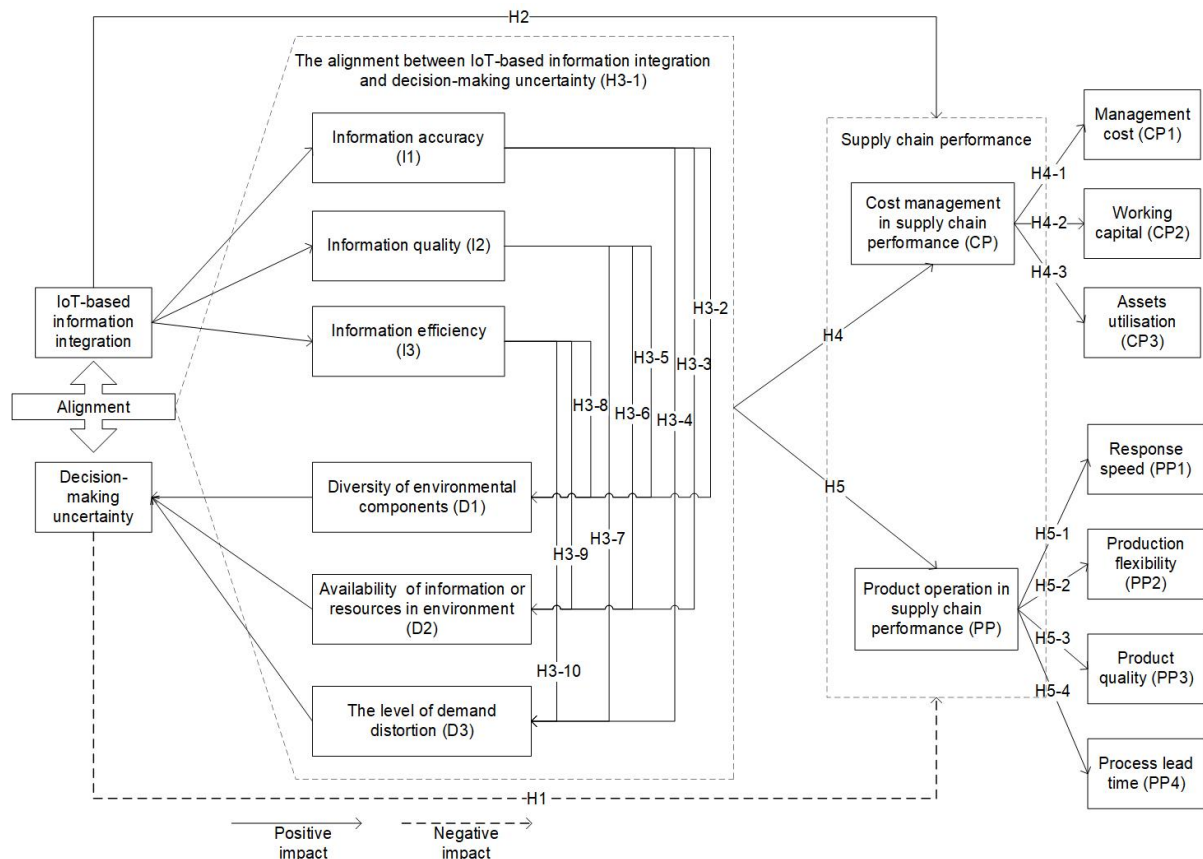


Figure 4-2). The hypotheses model indicates that IoT-based information integration has a direct positive impact on supply chain performance. In contrast, decision-making uncertainty has a direct negative impact on supply chain performance. IoT-based information integration and decision-making uncertainty align with each other and there are nine interactions inside this alignment. The alignment also positively impacts supply chain performance, both from cost management and production operations perspectives.

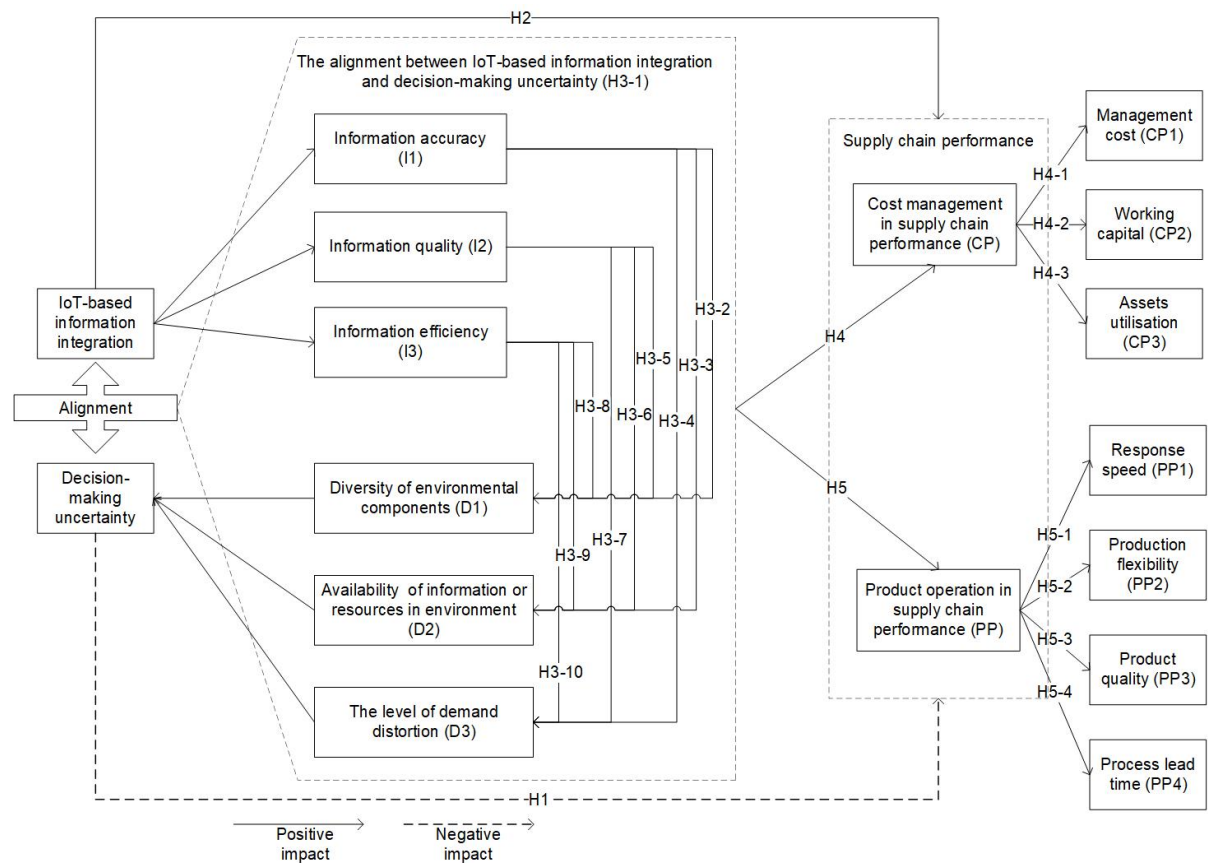


Figure 4-2. The hypotheses model

### 4.3 Research Methodology

This paper investigates the interaction between key factors and the role of the alignment between IoT-based information integration and decision-making uncertainty in supply chain performance. The research process followed is shown in Figure 4-3. The data is collected by a large-scale survey. The purpose of the survey is to ensure the data has wide coverage, meets the target standard, is sufficiently robust for analysis, and is effectively collected (Carbone and Moatti, 2011; Fernandes et al., 2022). The model in this paper is not dynamic, since the effect of time is excluded from the factors (Stermann, 2002; Jansen et al., 2018). SEM is used to analyse the data for the following reasons. Firstly, considering this paper's research questions and hypotheses, some of the variables in this study (decision-making uncertainty and information integration) cannot be directly observed. Using regression analysis, SEM can handle unobserved variables directly (latent variables), along with their multicollinearity, which occurs when two or more predictor variables are highly correlated (Belhadi et al., 2021). Moreover, one of the research aims is to test the theory-based relational framework based on IPT. SEM helps to determine whether the models developed based on the theory are valid and identify the necessary changes in the model, and it is used to examine the causal relationship between different variables (Şahin and Topal, 2019; Jihadi et al., 2020; Rehman Khan and Yu, 2021).

After identifying the factors for IoT-based information integration and decision-making uncertainty, and supply chain performance based on the literature review, data collection and analysis methodology was executed in four phases: (1) survey instrument development; (2) sampling design and data collection; (3) confirmatory analysis for reliability, convergent validity, and discriminant validity; and (4) hypothesis testing through SEM analysis. This paper describes each of the phases below.

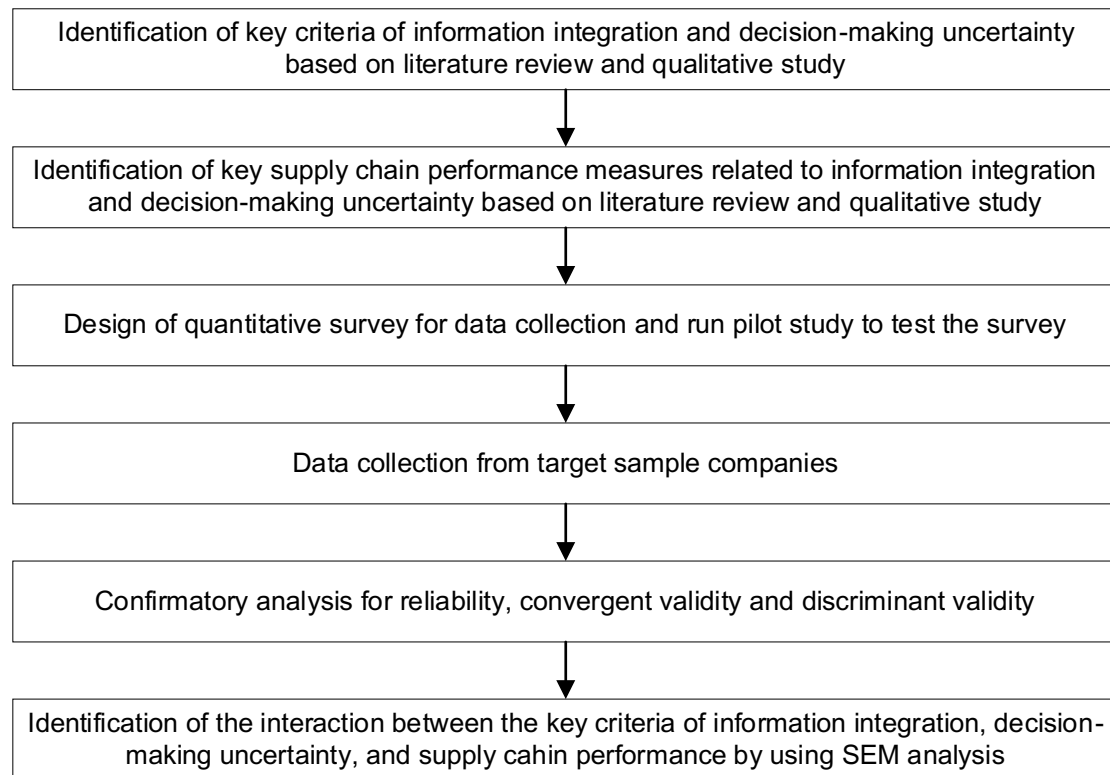


**Figure 4-3. Research steps for data collection and analysis**

### **4.3.1 Survey Instrument Development**

As illustrated in Section 4.2, the factors used to measure IoT-based information integration, decision-making uncertainty, and supply chain performance are identified based on previous studies and the findings of Paper 2. The formulation of constructs within the scale is guided by the direction of causality between the main construct and its factors (Peter et al., 2007). For instance, drawing on prior research (e.g., Rajaguru and Matanda, 2013; Pan et al., 2018; Eker and Eker, 2019) and the findings from Paper 2, the concept of decision-making uncertainty is considered formatively and is influenced by three distinct factors: environmental richness, environmental complexity, and the bullwhip effect. Rather than decision-making uncertainty being the cause of these factors, it is more appropriate to view it as a composite concept shaped collectively by these factors, each of which captures different facets of the construct. To elaborate further, environmental richness and complexity contribute to increased information processing needs from outside supply chains, while the bullwhip effect primarily results in heightened information processing needs between supply chain stakeholders. As a result, variations in each factor influence the definition and interpretation of decision-making uncertainty. Similar formative approaches have been employed to define other variables in this research, wherein each variable is considered a composite of its underlying factors. By considering the interplay between these factors,

researchers gain a more comprehensive understanding of the complex relationships within the constructs (Peter et al., 2007; Cao et al., 2015). Consequently, this study designed a scale that including 26 items following the existing survey instruments (Flynn et al., 2010; Lee et al., 2016; Belhadi et al., 2021) (shown in Table C- 1). Table 4-1 summarises the survey and the links to hypotheses. Detailed development of the scales is illustrated in Appendix C, Table C- 2.

| No.    | Description                                                                             | Likert scale | Link to hypotheses |
|--------|-----------------------------------------------------------------------------------------|--------------|--------------------|
| Part 1 | Demographic variables                                                                   | 7            | N/A                |
| Part 2 | Impact of decision-making uncertainty                                                   | 7            | H1                 |
| Part 3 | Impact of IoT-based information integration                                             | 7            | H2                 |
| Part 4 | The alignment between decision-making uncertainty and IoT-based information integration | 7            | H3-1 to H 3-10     |
| Part 5 | The alignment's impact on supply chain performance                                      | 7            | H4 to H5-4         |

**Table 4-1. The link between survey and hypotheses**

This paper chooses 7-point Likert scale because, as compared to other numbers of points on the scale, it results in stronger correlations with *t*-test results (Lewis, 1993), is a more suitable scale for online survey distribution (Finstad, 2010), and can produce more accurate data (Johns, 2010). Content validity was done in two steps. First, the items were reviewed by two academics and six practitioners to comment on clarity and appropriateness. Based on their feedback, this paper adjusted the items for the pilot study. The pilot study was conducted using the sample firms in Paper 2, since they were verified as appropriate samples for this research. This paper secured 16 respondents for the pilot study. Their answers were checked and testified with reference to the content validity ratio for the reasonableness of the survey instrument (Lawshe, 1975).

#### **4.3.2 Sampling Design and Data Collection**

The target population for this paper included senior executive and middle-level managers working in the fast fashion supply chain of China. This target population was selected to ensure all the respondents understand what the IoT is and how IoT applications are implemented in their supply chain. This knowledge is verified based on related questions in the cover letter of the survey to guarantee that answers are based on respondents' experience and that the collected data is representative and accurate. According to Hair et al. (2021), the minimum sample size for the PLS-SEM model depends on the maximum number of independent variables for a latent variable. In this paper, the maximum number of independent variables for a latent variable is 9.

Therefore, the minimum sample size is 150 based on the commonly used level of statistical power of 80% for detecting (with a 5% probability of error)  $R^2$  values of at least 0.1 in an endogenous variable (Hair et al., 2021).

A professional research agency in China was hired to collect the data. The agency has worked with many universities (such as the Massachusetts Institute of Technology, New York University, Hong Kong University of Science and Technology, Peking University, and Tsinghua University), and the research papers based on their data collection are received by top academic journals (e.g., *International Journal of Production Research*, *International Journal of Information Management*, *Journal of Management*, *Production and Operations Management*, *British Journal of Management*). The survey instrument was administered online, and a series of screening questions (e.g., regarding the respondents' job positions, working companies, and industries of practice) were included to find the qualified respondents for this study. In the agency's system, the respondents must first register and provide a certificate for their company positions. Then their profiles are verified by the agency, and only the approved ones can answer the questionnaires. Moreover, the acceptance rate per questionnaire of each respondent is recorded. The respondents with low acceptance rates are eliminated. All these measures are to ensure the quality of the recovered data. A total of 275 usable responses were collected. The market research company reported a response rate of 5.88%.

Table 4-2 lists the analysis of the respondent's demographic information. Middle-level managers in the fast fashion supply chain made up the majority (79.6%) of the study participants. Different functions in the supply chain were represented in the sample. Manufacturers represented 66.9% of the sample, while the remaining 33.1% of the participants included brand owners, raw material suppliers, and distributors. Based on the position composition of fast fashion industry and the distribution of supply chain stakeholders, the only shortfall in the samples is the number of suppliers of raw materials, which can be made up through subsequent data collection.

| <b><i>Respondent's<br/>position</i></b>    | <b><i>current</i></b> | No. | Percentage |
|--------------------------------------------|-----------------------|-----|------------|
| Senior executive                           |                       | 56  | 20.40%     |
| Mid-level management                       |                       | 219 | 79.60%     |
| <b><i>Function in the supply chain</i></b> |                       | No. | Percentage |
| Brand owner                                |                       | 26  | 9.50%      |
| Raw material supplier                      |                       | 25  | 9.10%      |
| Manufacturer                               |                       | 184 | 66.90%     |

|             |    |        |
|-------------|----|--------|
| Distributor | 40 | 14.50% |
|-------------|----|--------|

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**Table 4-2. Survey demographics**

Common method bias needs to be assessed if the data for independent and dependent variables are collected from same sample with the same survey instrument (Podsakoff et al., 2003). Following the suggestion of Podsakoff and Organ (1986), Harman's single-factor test is conducted to assess common method bias in this study. 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, the data was collected over a month, and the response rate is around 5%. Therefore, nonresponse bias is needed (Chen and Paulraj, 2004). This paper followed the conducted wave analysis recommended by former researchers to test the nonresponse bias (Armstrong and Overton, 1977; R. Kumar et al., 2020; Sinnandavar et al., 2018). The first 100 and last 100 responses were selected to test their independence (listed by the response date from the earliest to the latest). 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. The *t*-values range from -0.612 to 1.323, with a significance level ranging from 0.114 to 0.932. The test indicated no significant difference between the two periods of responses. Hence, it can be concluded that nonresponse bias does not significantly impact this study.

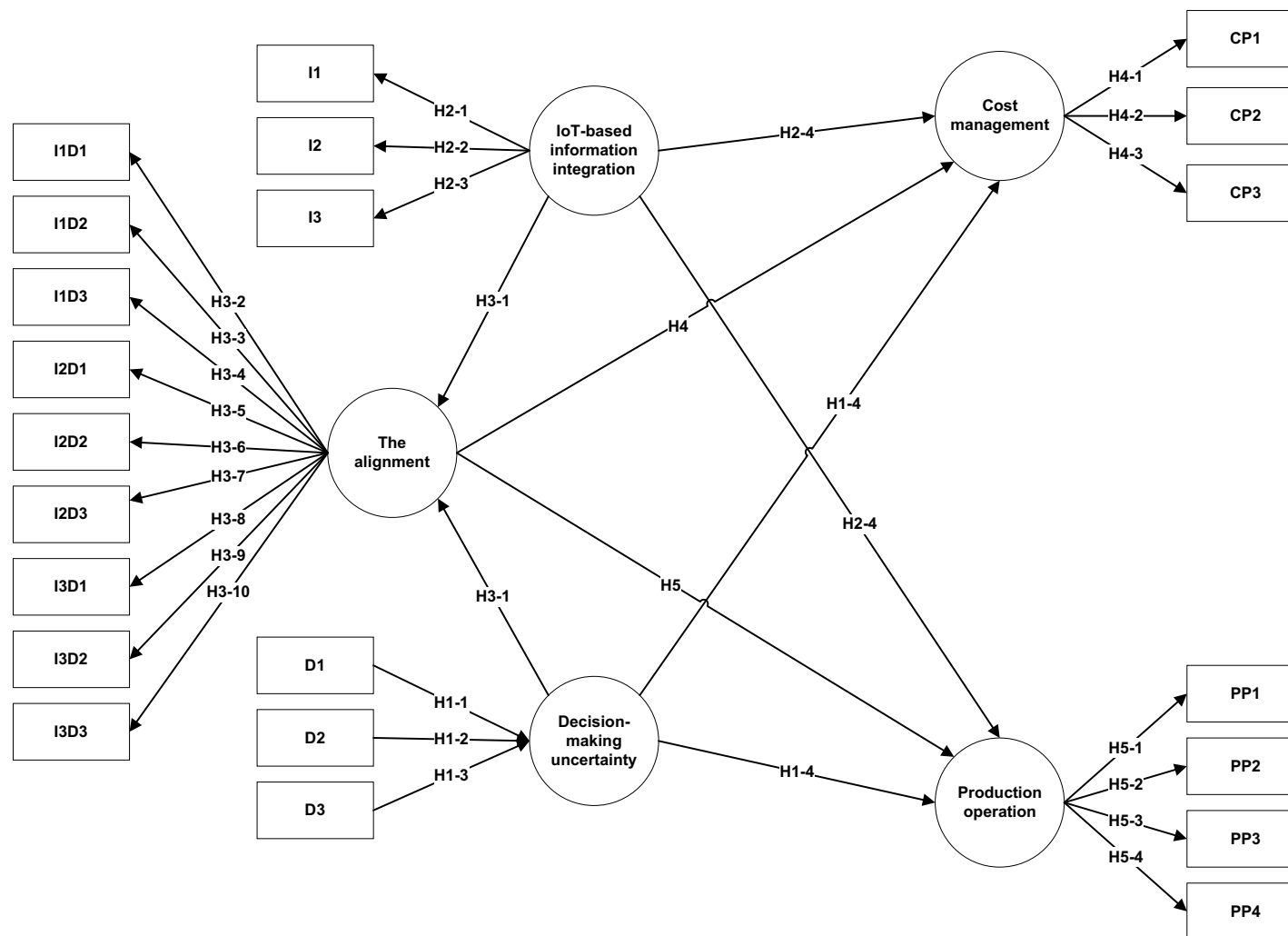


Figure 4-4. The SEM models

### 4.3.3 Confirmatory Analysis for Reliability, Convergent Validity, and Discriminant Validity

A two-step SEM approach will be used to analyse the data generated from the surveys. First, an exploratory factor analysis (EFA) will be conducted to rationalise the factors and build a comprehensive measurement model in line with the research framework. Second, confirmatory factor analysis (CFA) will be conducted to fit and validate a structural model based on the developed hypotheses model and assess the structural paths for causal relationships among the factors under investigation (Salam 2017; de Vass, Shee, and Miah 2018).

The proposed SEM model (Figure 4-4) was assessed based on EFA and CFA to ensure that the scales of observable factors for latent variables are appropriate and that the model is reliable (Szymczak et al., 2018; Falasca et al., 2022). The scales of observable factors for latent variables are listed in Table 4-3. EFA was conducted via IBM SPSS Statistics 28.0 to check the fit of the scales. By testing the data with 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. EFA analysis aims to test the scales of observable factors for each latent variable. The result (shown in Table 4-3) illustrates that the interaction between information quality and environmental complexity and the interaction between information efficiency and environmental complexity significantly deviate from other factors in the alignment. Similarly, the production quality in production performance significantly differs from other factors in supply chain performance. Therefore, I2D1, I3D1, and PP3 were omitted from further analysis.

| Latent variables                                                                        |                                                                                 | Factors                       | Reference                                                                                                                                                                                             | Component    |       |       |                    |
|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-------|-------|--------------------|
|                                                                                         |                                                                                 |                               |                                                                                                                                                                                                       | 1            | 2     | 3     | 4                  |
| Decision-making uncertainty                                                             | Environmental uncertainty                                                       | Environmental complexity (D1) | Aldrich, 1979; Castrogiovanni, 1991, Rajaguru and Matanda, 2013, Pan, Chen, and Ning, 2018                                                                                                            |              |       |       | <b>0.743</b>       |
|                                                                                         |                                                                                 | Environmental richness (D2)   |                                                                                                                                                                                                       |              |       | 0.521 | <b>0.617</b>       |
|                                                                                         | Industry uncertainty                                                            | Bullwhip effect (D3)          |                                                                                                                                                                                                       |              |       |       | <b>0.706</b>       |
| IoT-based information integration                                                       | The improvements in information collecting, selecting, and sharing processes    | Information accuracy (I1)     | Hwang and Rho, 2014; Ma et al., 2017; de Vass, Shee, and Miah, 2018; Tao and Qi, 2019                                                                                                                 | 0.405        |       |       | <b>0.512</b>       |
|                                                                                         |                                                                                 | Information quality (I2)      |                                                                                                                                                                                                       |              | 0.385 |       | <b>0.394</b>       |
|                                                                                         |                                                                                 | Information efficiency (I3)   |                                                                                                                                                                                                       |              |       |       | <b>0.787</b>       |
| The alignment between IoT-based information integration and decision-making uncertainty | The interactions between information accuracy and decision-making uncertainty   | I1D1                          | Chatfield et al., 2004; Badenhorst, Maurer and Brevis-Landsberg, 2013; Ge and Helfert, 2013; Lu et al., 2017; Zobel and Russell, 2017; Viet, Behdani and Bloemhof, 2018; Kolinski and Jaskolska, 2018 |              |       |       | 0.467              |
|                                                                                         |                                                                                 | I1D2                          |                                                                                                                                                                                                       |              |       |       | <b>0.515</b>       |
|                                                                                         |                                                                                 | I1D3                          |                                                                                                                                                                                                       |              |       |       | <b>0.581</b>       |
|                                                                                         | The interactions between information quality and decision-making uncertainty    | I2D1                          |                                                                                                                                                                                                       |              | 0.390 | 0.391 |                    |
|                                                                                         |                                                                                 | I2D2                          |                                                                                                                                                                                                       |              |       |       | <b>0.615</b>       |
|                                                                                         |                                                                                 | I2D3                          |                                                                                                                                                                                                       |              |       | 0.405 | <b>0.490</b>       |
|                                                                                         | The interactions between information efficiency and decision-making uncertainty | I3D1                          |                                                                                                                                                                                                       |              | 0.367 | 0.549 |                    |
|                                                                                         |                                                                                 | I3D2                          |                                                                                                                                                                                                       |              |       |       | <b>0.788</b>       |
|                                                                                         |                                                                                 | I3D3                          |                                                                                                                                                                                                       |              |       |       | <b>0.518</b> 0.326 |
| Supply chain performance                                                                | Supply chain cost                                                               | Management cost (CP1)         | Stefansson, 2002; Ge et al., 2004; Singh and Garg,                                                                                                                                                    | <b>0.692</b> |       |       |                    |
|                                                                                         |                                                                                 | Working capital (CP2)         |                                                                                                                                                                                                       | <b>0.592</b> |       | 0.352 |                    |

|                       |                              |                                                                                          |              |       |       |
|-----------------------|------------------------------|------------------------------------------------------------------------------------------|--------------|-------|-------|
|                       | Asset utilisation (CP3)      | 2015; Chakuu, Masi, and Godsell, 2019                                                    | <b>0.629</b> |       |       |
|                       | Response speed (PP1)         |                                                                                          | <b>0.621</b> |       |       |
|                       | Production flexibility (PP2) | Salam, 2017; Sanders and Wan, 2018; Birkel and Hartmann, 2019; Núñez-Merino et al., 2020 | <b>0.668</b> |       |       |
| Production operations | Production quality (PP3)     |                                                                                          | 0.349        | 0.446 | 0.391 |
|                       | Operation processing (PP4)   |                                                                                          | <b>0.672</b> |       |       |

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Extraction Method: Principal component analysis (PCA).

Rotation Method: Varimax with Kaiser normalization.

Rotated Component Matrix

a Rotation converged in 6 iterations.

**Table 4-3. The components of each latent variable**

The measurement model of this study is reflective of relationships, and the assessment of the model included, individual consistency reliability, convergent validity, and discriminant validity (shown in Table 4-4 and Table 4-5). The individual consistency reliability was tested via Cronbach's  $\alpha$ , the squared multiple correlation coefficient ( $R^2$ ), and composite reliability (CR). The Cronbach's  $\alpha$  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 et al. 2021). The values of standardised factor loading of the 16 factors entries on the corresponding latent variable vary from 0.721 to 0.848, higher than the minimum requirement 0.70 (Hair et al., 2021). I1D3, I2D2, and I3D2 were deleted because they have lower outer loading in the model ( $< 0.7$ ) (Hair et al. 2021). Further, the deletion of these three factors increased the content validity and average variance extracted (Hulland, 1999). The average variance extracted (AVE) value of each construct varies from 0.578 to 0.636, higher than the recommended threshold value of 0.50. The results show that the measurement scales of the constructs have high convergent validity in the hypotheses model in this study. The validity of the distinction between the variables was tested by cross-loading and the Fornell-Larcker criterion. The results show that the discrimination validity is adequate.

| Latent variables                  | Factors | Loading | VIF   | Cronbach's $\alpha$ | 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 alignment                     | 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 |                     |                       |                                  |
| Supply chain cost                 | 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 |                     |                       |                                  |

**Table 4-4. Consistency reliability and convergent validity**

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

**Table 4-5. Discriminant validity**

Collinearity issues were checked by examining variance inflation factor (VIF) values. The result showed that all the estimated VIF values were below the threshold value of 5 (Hair et al., 2021). Therefore, no collinearity issues were found in the model.

The key factors' outer loadings are also assessed. 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 factors 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.

## **4.4 Result and Analysis**

### **4.4.1 Hypothesis Testing**

Six hypotheses were rejected due to the significant deviations to other factors (H3-5, linked to factor I2D1; H3-8, linked to factor I3D1; and H5-3, linked to factor PP3) and lower loading values in convergent validity (H3-4, linked to factor I1D3; H3-6, linked to factor and I2D2; and H3-9, linked to factor I3D2). The remaining research hypotheses were analysed by PLS-SEM software (SmartPLS 4.0). Bootstrapping method (5,000 subsamples) was used to evaluate the significance of the standardised path coefficients. Table 4-6 illustrates the results. Following the same logic, H3-2, H3-3, H3-7, and H3-9 are supported. H1-3 explored the relationship between decision-making uncertainty and supply chain performance. In this respect, decision-making uncertainty had a statistically significant and directly negative effect on supply chain performance at the 0.05 level. H1 is, therefore, supported with standardised path coefficients of -0.140/-0.206 and *p*-values of 0.019/0.001. IoT-based information integration was also found to have a significant direct positive effect on supply chain performance with standardised path coefficients of 0.361/0.289 and *p*-values smaller than 0.001. Thus, the results provide empirical support for H2, which analysed the link between IoT-based information integration and supply chain performance in the fast fashion industry.

With respect to the relationship between decision-making uncertainty and IoT-based information integration, decision-making uncertainty was found to have a significant direct negative effect on alignment, with a standardised path coefficient of -0.384 and a *p*-value smaller than 0.001, and IoT-based information integration was found to have a significant direct positive effect on alignment, with a standardised path coefficient of 0.393 and a *p*-value smaller than 0.001. H3-1 is, therefore, empirically supported by the study results. The last two research hypotheses evaluated the relationship between alignment

and supply chain cost/production operations in supply chain performance. The results showed that alignment had a significant direct positive effect on supply chain cost and production operations in supply chain performance. H4 and H5 are, therefore, empirically supported with a standardised path coefficient of 0.321 and a  $p$ -value smaller than 0.001 and a standardised path coefficient of 0.309 and a  $p$ -value smaller than 0.001, respectively. In addition, the outer loadings of CP1, CP2, CP3, PP1, PP2, and PP4 are all over 0.7, and  $p$ -values are smaller than 0.001. The results indicate that H4-1, H4-2, H4-3, H5-1, H5-2, and H5-4 are supported.

Regarding the  $R^2$  values of the endogenous latent variables, values of 0.448 for alignment, 0.487 for supply chain cost, and 0.455 for production operations were significant at the 0.001 level (shown in Figure 4-5). According to Hair et al. (2021),  $R^2$  values of 0.75 are considered substantial, values around 0.50 as moderate and values around 0.25 as weak. The  $R^2$  values in the model were deemed moderate. This result shows that supply chain cost and production operations are explained by the variables (IoT-based information integration, decision-making uncertainty, and the alignment) that this paper selects.

| Hypotheses | Path                                                       | Loading | Path coefficient ( $\beta$ ) | Standard deviation (STDEV) | t-statistics ( O/STDEV ) | p-values | Conclusion    |
|------------|------------------------------------------------------------|---------|------------------------------|----------------------------|--------------------------|----------|---------------|
| H1         | Decision-making uncertainty -> Supply chain cost           | -       | -0.140                       | 0.060                      | 2.343                    | 0.019    | Supported     |
| H1         | Decision-making uncertainty -> Production operations       | -       | -0.206                       | 0.061                      | 3.376                    | 0.001    | Supported     |
| H2         | IoT-based information integration -> Supply chain cost     | -       | 0.361                        | 0.061                      | 5.945                    | 0.000    | Supported     |
| H2         | IoT-based information integration -> Production operations | -       | 0.289                        | 0.060                      | 4.793                    | 0.000    | Supported     |
| H3-1       | Decision-making uncertainty -> Alignment                   | -       | -0.384                       | 0.050                      | 7.750                    | 0.000    | Supported     |
| H3-1       | IoT-based information integration -> Alignment             | -       | 0.393                        | 0.052                      | 7.593                    | 0.000    | Supported     |
| H3-2       | I1D1 <- Alignment                                          | 0.721   | -                            | 0.036                      | 20.299                   | 0.000    | Supported     |
| H3-3       | I1D2 <- Alignment                                          | 0.748   | -                            | 0.030                      | 25.002                   | 0.000    | Supported     |
| H3-4       | I1D3 <- Alignment                                          | 0.693   | -                            | -                          | -                        | -        | Not supported |
| H3-5       | I2D1 <- Alignment                                          | -       | -                            | -                          | -                        | -        | Not supported |
| H3-6       | I2D2 <- Alignment                                          | 0.659   | -                            | -                          | -                        | -        | Not supported |
| H3-7       | I2D3 <- Alignment                                          | 0.775   | -                            | 0.028                      | 27.945                   | 0.000    | Supported     |

|       |                                    |       |       |       |        |       |               |
|-------|------------------------------------|-------|-------|-------|--------|-------|---------------|
| H3-8  | I3D1 <- Alignment                  | -     | -     | -     | -      | -     | Not supported |
| H3-9  | I3D2 <- Alignment                  | 0.675 | -     | -     | -      | -     | Not supported |
| H3-10 | I3D3 <- Alignment                  | 0.797 | -     | 0.024 | 33.142 | 0.000 | Supported     |
| H4    | Alignment -> Supply chain cost     | -     | 0.321 | 0.058 | 5.575  | 0.000 | Supported     |
| H4-1  | CP1 <- Supply chain cost           | 0.815 | -     | 0.021 | 39.461 | 0.000 | Supported     |
| H4-2  | CP2 <- Supply chain cost           | 0.765 | -     | 0.028 | 26.962 | 0.000 | Supported     |
| H4-3  | CP3 <- Supply chain cost           | 0.774 | -     | 0.033 | 23.442 | 0.000 | Supported     |
| H5    | Alignment -> Production operations | -     | 0.309 | 0.057 | 5.421  | 0.000 | Supported     |
| H5-1  | PP1 <- Production operations       | 0.777 | -     | 0.027 | 28.972 | 0.000 | Supported     |
| H5-2  | PP2 <- Production operations       | 0.749 | -     | 0.034 | 21.730 | 0.000 | Supported     |
| H5-3  | PP3 <- Production operations       | -     | -     | -     | -      | -     | Not supported |
| H5-4  | PP4 <- Production operations       | 0.831 | -     | 0.022 | 38.565 | 0.000 | Supported     |

**Table 4-6. Summary of hypothesis testing**

#### 4.4.2 Mediation Analysis

Based on the findings obtained in the previous section, the mediating role of the alignment in the link between decision-making uncertainty, IoT-based information integration and supply chain performance (supply chain cost and production operations) was further evaluated. The bootstrap approach proposed by Hair et al. (2021) was used to investigate the mediation.

The direct impacts of decision-making uncertainty and IoT-based information integration on supply chain performance were first evaluated. The results (shown in Table 4-7 and Figure 4-5) 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 ( $p < 0.001$ ). The links between decision-making uncertainty, IoT-based information integration, and alignment were explored next. The model results indicate the existence of a statistically significant relationship between decision-making uncertainty and the proposed mediator (alignment) ( $p < 0.001$ ), as well as IoT-based information integration and the proposed mediator (alignment) ( $p < 0.001$ ). Finally, the links between decision-making uncertainty, IoT-based information integration, and alignment and supply chain performance variables (supply chain cost and production operations) were simultaneously assessed. The results support the relationship between alignment and supply chain performance (supply chain cost and production operations) ( $p < 0.001$ ). On the other hand, the indirect link between decision-making uncertainty and supply chain performance (supply chain cost and production operations) – through alignment – and the indirect link between IoT-based information integration and supply chain performance (Supply chain cost and Production operations) – through alignment – are all found to be statistically significant at the 0.001 level.

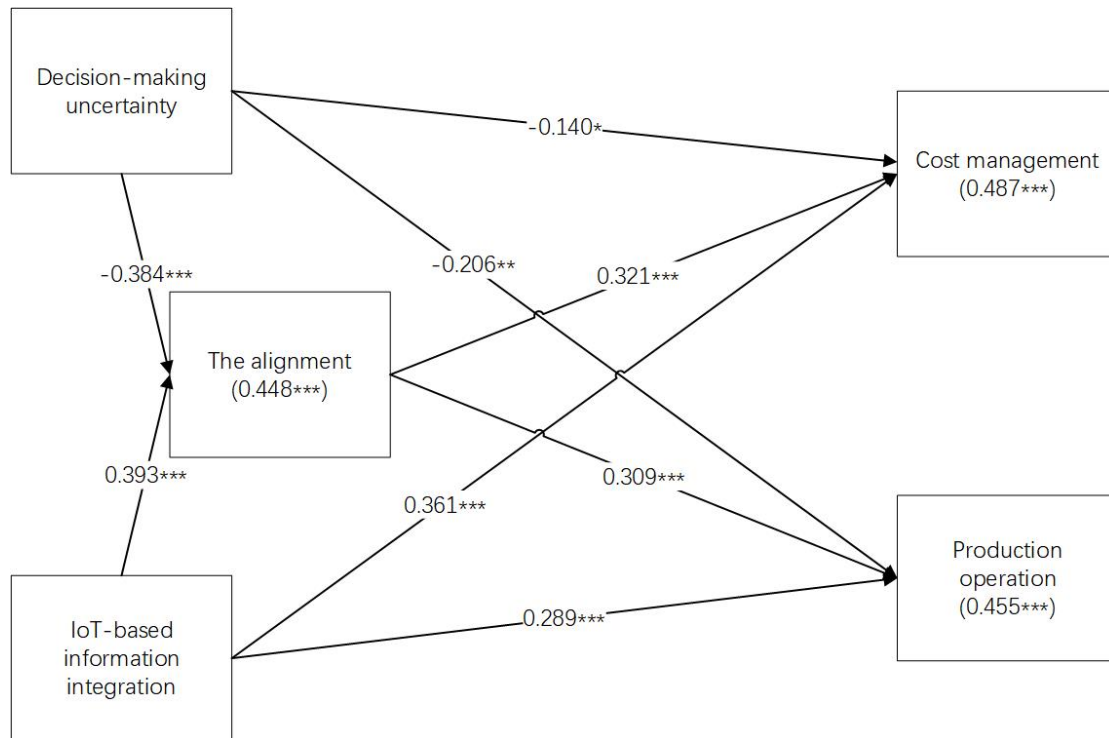


**Figure 4-5. Model results. Note: Standardised path coefficients,  $R^2$  values in parentheses (\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ )**

Synthesising the analysis results, it can be concluded that alignment has a partially mediating impact on the relationship among decision-making uncertainty, IoT-based information integration, and supply chain performance (Table 4-7). This result supports H4 and H5.

| Effect                                                  | Direct   | Indirect  | Total     | Conclusion                        |
|---------------------------------------------------------|----------|-----------|-----------|-----------------------------------|
| Decision-making uncertainty -> Supply chain cost        | -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 -> Supply chain cost  | 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): \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$

**Table 4-7. Summary of mediation analysis**

## 4.5 Discussion

The analysis results (as shown in Table 4-6 and Figure 4-5) indicate that environmental complexity, richness, and the bullwhip effect in decision-making uncertainty, and the improvement of information accuracy, quality, and efficiency in IoT-based information integration, are the key factors highly related to the alignment between decision-making uncertainty and IoT-based information integration. This study visualises the relationship between decision-making uncertainty and IoT-based information integration. This paper has hypothesised that both decision-making uncertainty and IoT-based information integration directly impact supply chain performance. The relevant hypotheses (H1-3, H2-4) are supported. In the model, decision-making uncertainty produces a negative effect on supply chain performance. This result parallels those of previous studies (Gao et al., 2005; Sniazhko, 2019; Wu et al., 2019), but uniquely this paper proposes specific factors (the 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 has proposed that IoT-based information integration has a positive impact, and this hypothesis is supported ( $t > 4; p < 0.001$ ). The finding is also well supported the previous literature (Yu, 2015; de Vass et al., 2018). This paper further identifies that the implementation of IoT applications in information integration improves information accuracy, quality, and efficiency, providing real-time information to increase the information processing capability and support the stakeholders' decision-making process. Increased information processing capability to fulfil the information processing needs improves supply chain performance (supply chain costs and production operations in the model of this paper).

The other hypothesis (H3-1) states that IoT-based information integration is highly related to decision-making uncertainty, and they align ( $t > 7; p < 0.001$ ). The results also reflect that the negative effect of decision-making uncertainty on the alignment ( $\beta = -0.384$ ) is almost the same as the positive effect of IoT-based 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 applications in information integration aligns with the level of decision-making uncertainty in the supply chain. This result provides empirical evidence for previous literature that explains the relationship between decision-making uncertainty and information integration based on IPT (Wu et al., 2013; Wong et al., 2015; Moser et al., 2017). Following the analysis result in Paper 2, this paper then divided the alignment between decision-making uncertainty and IoT-based information integration into the interactions of environmental

complexity, namely richness and the bullwhip effect, with the improvement of information accuracy, quality, and efficiency.

The associated hypotheses are not fully supported. Only the interaction between information accuracy and environmental complexity (H3-2), the interaction between information accuracy and environmental richness (H3-3), the interaction between information quality and bullwhip effect (H3-7), and the interaction between information efficiency and bullwhip effect (H3-10) are verified with an outer loading over 0.7 and a  $p$ -value smaller than 0.001. These findings demonstrate that the other interactions between key factors are not significant in this model. The results contrast previous studies indicating that the improvement of information quality and efficiency reduces environmental uncertainty in the supply chain (Nagarajan et al., 2013; Singh and Garg, 2015; James and George, 2018). The reason for this disagreement may be that the implementation of IoT applications remains nascent in the samples. The improvement of information quality and efficiency at this stage does not strongly impact environmental uncertainty. Therefore, it is suggested that at the initial stage of implementing IoT applications, the improvement in information quality and efficiency cannot solve the issues caused by environmental uncertainty. This finding can also explain why the implementation of IoT applications does not generally lead to short-term financial benefits. Specifically, the analysis result shows that environmental uncertainty (environmental complexity and environmental richness) is a key factor in decision-making uncertainty, such that decision-making uncertainty is verified to significantly and negatively impact supply chain costs. Thus, reducing environmental uncertainty can improve financial performance. However, the research results of this paper show that the initial implementation of IoT applications cannot solve the problems caused by the environmental uncertainty, so it cannot bring short-term economic benefits.

The study also proposes that the alignment between decision-making uncertainty and IoT-based information integration significantly impacts supply chain performance. The hypotheses (H4 and H5) are supported ( $t > 5; p < 0.001$ ). The alignment positively impacts supply chain performance. The findings align with the literature's focus on supply chain performance (Wong et al., 2015; Kumar et al., 2020; García-Alcaraz et al., 2021). Moreover, differing from previous studies, this study listed the impacts of the alignment between decision-making uncertainty and IoT-based information integration on different aspects of supply chain performance. The impact on supply chain cost relates mainly to management cost reduction (H4-1), asset utilisation improvement (H4-2), and increasing working capital (H4-3). The impact on production operations is reflected in the improvement of response speed (H5-1), flexibility (H5-2), and operation processing (H5-4). Previous studies have mentioned some of the

effects in their findings but none have tested and synthesised all the detailed effects of the alignment on supply chain performance. This paper also found that the alignment does not directly impact product quality in the model (H5-3). In the processes of information integration, production quality is mainly exchanged among stakeholders as information, and the improvement of production quality occurs in other parts of supply chain integration (e.g., customer integration or supplier integration) (Wong, Boon-Itt, and Wong, 2011; Samaranayake and Laosirihongthong, 2016).

In addition, the analysis results support the theoretical framework based on IPT, which indicates that the alignment between decision-making uncertainty and IoT-based information integration improves supply chain performance. The indirect relationship between decision-making uncertainty, IoT-based information integration, and supply chain performance through the alignment was also found and assessed. Previous research based on IPT focussed only on the interactions between decision-making uncertainty and information integration, and the direct impacts of decision-making uncertainty on supply chain performance were not discussed, considering decision-making uncertainty as a full mediating variable in the relationship between information integration and supply chain performance by many scholars (Wong et al., 2011; Zimmermann et al., 2020). Differing from their studies, the findings in this paper show that the alignment directly influences supply chain performance, and the negative impact of decision-making uncertainty, and the positive impact of IoT-based information integration are both significant ( $t > 1.96; p < 0.05$ ) and balanced. Specifically, the model provides a detailed explanation of the mediating role of the alignment: the analysis results show that the alignment is a complementary mediator in the relationship between IoT-based information integration and supply chain performance and a competitive mediator in the relationship between decision-making uncertainty and supply chain performance.

Based on the above discussion, a detailed framework of the relationship between information integration and decision-making uncertainty is developed (Figure 4 6). It is verified in this study that information accuracy, efficiency and quality are the key factors for information integration, and environmental complexity, richness, and bullwhip effect are the key factors for decision-making uncertainty. The empirical evidence in this study supports five key interactions between these key factors. The direct impacts of information integration and decision-making uncertainty on supply chain performance are also supported. Therefore, the finding in this study has enriched the missing parts of the theoretical framework based on IPT, providing a detailed explanation of the interactions in the alignment and illustrating the alignment's resulting impact on supply chain performance.

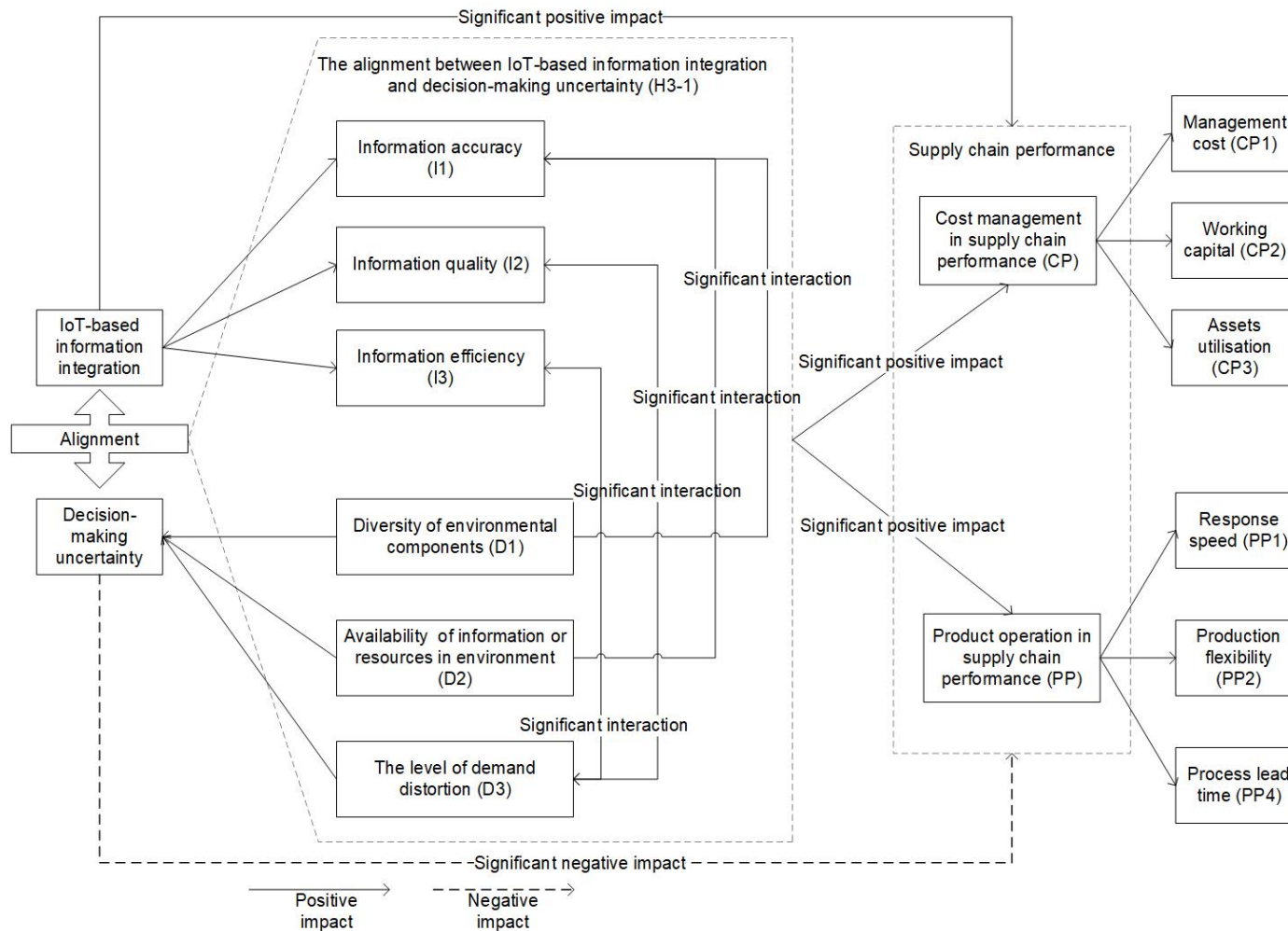


**Figure 4-6. The modified theoretical framework of the alignment between IoT-based information integration and decision-making uncertainty**

## 4.6 Conclusion

This paper had focussed on the relationship between decision-making uncertainty and IoT-based information integration and its impact on supply chain performance. It establishes a structural equation model and uses survey data from the fast fashion industry in China via SmartPLS to analyse the theory-based relation framework revised in Paper 2 and verify the hypotheses. The following conclusions can be drawn.

First, key factors derived from the existing literature of decision-making uncertainty and information integration after the implementation of IoT applications in the supply chain are researched via empirical testing. The analysis results confirm the importance of key factors in decision-making uncertainty (environmental complexity, environmental richness, and the bullwhip effect) and IoT-based information integration (information quality, information accuracy, and information efficiency). This paper proposes that the alignment between decision-making uncertainty and IoT-based information integration is composed of the interactions of the key factors. Nine interactions of these key factors are assessed in the SEM models. According to the analysis result, this paper concludes that the alignment arises from the interactions between information accuracy and environmental complexity, information accuracy and environmental richness, information quality and the bullwhip effect, and information efficiency and the bullwhip effect. The rest of the interactions are found to be insignificant. Therefore, the first research question is answered.

Furthermore, the findings identify several aspects of supply chain performance in the relationships among decision-making uncertainty, IoT-based information integration, and supply chain performance. Synthesising the results of Paper 2, the key factors of the two aspects of supply chain performance are identified: supply chain cost (management costs, working capital, and asset utilisation) and production operations (response speed, production flexibility, and process efficiency). Through the path coefficients, it is found that decision-making uncertainty and IoT-based information integration have statistically significant and direct impacts on supply chain performance. Therefore, the key factors of decision-making uncertainty and IoT-based information integration correspond to the key factors in supply chain performance. In addition, the impact of the alignment between decision-making uncertainty and IoT-based information integration on supply chain performance is also evaluated. The results demonstrates that the alignment significantly and positively impacts the key factors of supply chain performance. Synthesising these findings, this paper concludes that the alignment positively impacts supply chain cost (management costs, working capital, and asset utilisation) and production operations (response

speed, production flexibility, and process efficiency) in supply chain performance directly and through the partial mediating role. Thus, the second research question is answered.

#### **4.6.1 Theoretical Implications**

The findings parallel those of previous studies on the information integration and decision-making uncertainty relationship (Gao et al., 2005; Sniazhko, 2019; Wu et al., 2019) and its influence on supply chain performance (Wong et al., 2015; Kumar et al., 2020; García-Alcaraz et al., 2021), but advance the research in this area in the following ways.

First, based on the findings of Paper 2, this study introduces and validates four interactions between the key factors in the alignment between IoT-based information integration and decision-making uncertainty by disassembling the alignment into the interaction between information accuracy and environmental complexity, the interaction between information accuracy and environmental richness, the interaction between information quality and bullwhip effect, and the interaction between information efficiency and the bullwhip effect. A detailed explanation of the relationship between decision-making uncertainty and IoT-based information integration has not been made in the supply chain management literature. In this respect, this study first verified the importance of the key factors, and then their interactions are evaluated. As such, the alignment is visualised. This research represents the first empirical study to explain the detailed interactions in the relationship between information integration and decision-making uncertainty.

Second, the findings in this study also provide empirical evidence for the theoretical associations proposed by former studies (Gao et al., 2005; Sniazhko, 2019; Wu et al., 2019). Specifically, former studies confirmed a relationship between decision-making uncertainty and IoT-based information integration but haven't provided a detailed explanation of this relationship. This study explains the specific interaction between the key factors in IoT-based information integration and decision-making uncertainty by analysing the empirical data from fast fashion supply chain stakeholders.

Third, this paper assesses the direct effects of decision-making uncertainty and IoT-based information integration on supply chain management based on empirical data analysis. Although recent research has paid increasing interest to the relationship between decision-making uncertainty and information integration (Chen et al., 2014; Gao, 2017), the direct impact of decision-making uncertainty on supply chain performance has not been discussed. This study is unique in that it considers the implementation of IoT applications in the supply chain, the

specific interactions in the relationship, and the specific impacts on supply chain performance. The findings suggest that the direct impacts of decision-making uncertainty and IoT-based information integration on supply chain performance are significant. This finding proves that decision-making uncertainty and IoT-based information integration impact supply chain performance through their alignment and directly impact supply chain performance through the changes in key factors. Consequently, the paper proposes that the alignment has a competitive and complementary impact on the relationships among decision-making uncertainty, IoT-based information integration, and supply chain performance. Thus, a partial mediating role of the alignment is identified.

#### **4.6.2 Managerial Implications**

First, this paper identifies the key factors of decision-making uncertainty and information integration after implementing IoT applications in the supply chain. Focussing on and improving the information processing capability in supply chain management helps supply chain stakeholders to reduce the negative impact of decision-making uncertainty on supply chain performance (Sreekumar and Rajmohan, 2019; Yang et al., 2021). This finding can be used to develop clear key performance indicators for supply chain stakeholders to implement IoT applications in information integration.

Second, this paper proposes that it is essential for supply chain managers to evaluate the level of decision-making uncertainty before implementing IoT applications in the supply chain. It highlights that if the issues caused by environmental uncertainty and industry uncertainty are insignificant, there is no need to implement IoT applications. Only environmental complexity, environmental richness, and the bullwhip effect in decision-making uncertainty interact with IoT-based information integration. Thus, if the supply chain stakeholder suffers firm uncertainty the most, there is no use in implementing IoT applications.

Third, the findings of this research raise some issues that need supply chain managers' attention when implementing IoT applications. For instance, the findings show that implementing IoT applications can positively impact supply chain performance when commensurate with the level of decision-making uncertainty suffered by supply chain stakeholders. Supply chain managers should be fully aware of the importance of the alignment in supply chain management when implementing IoT applications (de Vass et al., 2018; Kumar et al., 2020). In addition, according to the path analysis results and the load size in each element of the path model (Table 5 and Figure 6), the alignment between decision-making uncertainty and IoT-based information integration positively

impacts the supply chain cost and production operations in supply chain performance. Product quality is not included in the supply chain performance factors impacted by the alignment because the impact is not significant. Supply chain managers should note this when implementing IoT applications in information integration.

#### **4.6.3 Limitations and Future Research Directions**

The study contributes to the knowledge on the relationships among decision-making uncertainty, IoT-based information integration, and supply chain performance, identifying the key factors in this relationship and visualising the alignment between decision-making uncertainty and IoT-based information integration. However, it faces certain limitations. First, there is a limitation associated with endogeneity. This study chooses the fast fashion supply chain with a high decision-making uncertainty level. The situation of lower decision-making uncertainty is not considered. It makes this study a single-informant study. It is acknowledged that the single-informant study potentially makes it difficult to accurately establish the relationship between information integration and decision-making uncertainty in consideration of all decision-making uncertainty levels. Second, the research question focuses on the changes in supply chain management after implementing IoT applications. Thus, when selecting the samples, this research only considered the organisations that implemented or planned to implement IoT applications. Organisations without the implementation of IoT applications are excluded. This exclusion may cause sample bias because some organisations without implementation have evaluated and decided to implement IoT applications. To address this limitation, this study included respondents from all parts of the supply chain in the sample. Stratified sampling is conducted to ensure that each role in the supply chain is adequately represented in the sample, which reduces the bias (Bhandari, 2023). Third, this study considers IoT-based information integration to align with decision-making uncertainty in the supply chain and demonstrates that this alignment improves supply chain performance. Additional research should explore the prevalence of the alignment 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 direction of research. Moreover, this study used the fast fashion supply chain in China as the target sample, and the implementation of IoT applications in the fast fashion supply chain remains underdeveloped. Therefore, this study is more applicable to industries just starting to implement or preparing to start implementing IoT applications. The implementation of IoT applications may occur at higher levels in other industries. This research can be extended to check whether the higher implementation levels of IoT applications in information integration in other industries generate the same

findings. Such confirmatory studies would enhance the external validity of this research.

## Reference for Chapter 4

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## **5 Conclusion**

### **5.1 Research Findings and Fulfilment of Research Objectives**

This PhD research has aimed to identify the relationship between information integration and decision-making uncertainty after implementing IoT applications in the supply chain and to establish the effect of this relationship on supply chain performance. The research aim further divides into five research objectives, for which the three papers obtain specific research results. Table 5-1 presents the link between the research objectives, the three papers, and the key findings.

Paper 1 (Chapter 2) addresses Objective 1. Based on a systematic literature review (SLR) of 86 journal papers, an information processing theory (IPT) based a relational framework was generated. The framework divides decision-making uncertainty into environmental, industry, and firm uncertainty. Information integration is divided between technology-based and collaboration-based, and the relationship between information integration and decision-making uncertainty is described based on IPT (illustrated in Figure 2-8). Moreover, the framework proposes that environmental and industry uncertainty are important drivers that increase information processing needs and strengthen supply chain stakeholders' willingness to implement information integration. ICTs are commonly used to support information integration and enhance information processing capability in the supply chain. The review demonstrates a fit between information integration and decision-making uncertainty, and this fit impacts supply chain performance.

Paper 2 (Chapter 3) contributes to Objectives 2 and 3. Drawing on the theory-based relational framework developed in Paper 1, a multiple-case study is conducted to investigate the key factors in decision-making uncertainty and information integration, the alignment between them, and the alignment's impact on supply chain performance after the implementation of IoT applications. According to the 30 respondents of 18 stakeholders in three fast fashion supply chains, the findings show that the implementation of IoT applications impacts information accuracy, quality, and efficiency in information integration. These three factors interact with environmental uncertainty (environmental complexity and richness) and industry uncertainty (the bullwhip effect). Their interactions impact supply chain costs and production operations. The findings of Paper 2 provide empirical evidence and enrichment for the theoretical constructs identified in Paper 1.

The interactions among the key factors form the alignment between information integration and decision-making uncertainty. The findings suggest that the alignment results from the interactions among the information accuracy, quality, and efficiency and environmental complexity, richness, and the bullwhip effect.

These findings in Paper 2 demonstrate an alignment between information integration and decision-making uncertainty as the result of these interactions. This explanation verifies that the alignment corresponds to the concept of fit in IPT (Galbraith, 1973; Tushman and Nadler, 1980). The alignment's impacts on supply chain costs and production operations are also illustrated.

Objectives 4 and 5 are addressed in Paper 3 (Chapter 4). The survey-based PLS-SEM analysis provides empirical evidence for the existence of key factors in IoT-based information integration, decision-making uncertainty, and supply chain performance. The result of the analysis in Paper 3 also demonstrates the existence of the alignment between IoT-based information integration and decision-making uncertainty. The analysis of Paper 2 evaluates the significance of the factors, triangulating the findings of Paper 2 by verifying that all the factors are key factors in IoT-based information integration and decision-making uncertainty. The factors for supply chain performance are also examined. Six out of the seven hypotheses are supported, but product quality is found not to be a key factor for production operations linked to the impact of the alignment.

In terms of Objective 5, the impact of IoT-based information integration on supply chain performance, the impact of decision-making uncertainty on supply chain performance, and the alignment's impact on supply chain performance are all evaluated. The direct impacts of IoT-based information integration supply chain performance is significant and positive, whereas decision-making uncertainty negatively impacts supply chain performance. The alignment between information integration and decision-making uncertainty also has a significant and positive impact on supply chain performance. These findings illustrate the partial mediating role of the alignment between information integration and decision-making uncertainty in the relationships among IoT-based information integration, decision-making uncertainty, and supply chain performance. The analysis result is interpreted based on the PLS-SEM analysis of quantitative data of 275 useable responses from fast fashion supply chain practitioners. The findings also propose that the initial implementation of IoT applications cannot solve the problems caused by environmental uncertainty, explaining why supply chain stakeholders do not report substantial short-term outcomes as a result of implementing IoT-based information integration (Boos et al., 2013; Hofmann and Rüscher, 2017).

| Research objectives                                                                                                                                                                                                  | Findings                                                                                                                                                                                                                                                                                                                                                                                                                                   | Paper | Chapter |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------|
| Objective 1. To provide an overview of the extant literature for the relationships among ICT applications, information integration, decision-making uncertainty, and supply chain performance in FMCG supply chains. | <ul style="list-style-type: none"> <li>Identifies several common ICTs and strategies implemented for information integration</li> </ul>                                                                                                                                                                                                                                                                                                    | 1     | 2       |
|                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>Proposes that ICTs help to provide both the technical infrastructure and the practical methods for technology-based information integration and increase information processing capability</li> </ul>                                                                                                                                                                                               | 1     | 2       |
|                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>Indicates that environmental uncertainty is an external driver and industry uncertainty is an internal driver of information integration, both of which increase information processing needs and enhance supply chain stakeholders' willingness to implement information integration, whereas little evidence shows the connection between firm uncertainty and information integration</li> </ul> | 1     | 2       |
|                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>Points out that ICT-supported information integration fits with a higher level of decision-making uncertainty in the supply chain. If the fit between decision-making uncertainty and information integration implementation cannot be achieved, it will negatively affect supply chain performance</li> </ul>                                                                                      | 1     | 2       |
|                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>Develops a theory-based relational framework based on IPT that describes the relationship between information integration and decision-making uncertainty in the FMCG supply chain</li> </ul>                                                                                                                                                                                                       | 1     | 2       |
| Objective 2. To identify the key factors in the relationship between information integration and decision-making uncertainty.                                                                                        | <ul style="list-style-type: none"> <li>Illustrates that IoT applications must be transformed into the firm's resources when integrated with internal operations.</li> </ul>                                                                                                                                                                                                                                                                | 2     | 3       |
|                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>Shows that the implementation of IoT applications has four stages: information collecting process, information selecting process, information-sharing process and decision-making process</li> </ul>                                                                                                                                                                                                | 2     | 3       |
|                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>Suggests that the implementation of IoT applications in information integration or IoT-based information integration enhances information processing capability by improving information accuracy, information quality, and information efficiency in the supply chain</li> </ul>                                                                                                                   | 2     | 3       |
|                                                                                                                                                                                                                      | <ul style="list-style-type: none"> <li>Indicates that information security is positively impacted by IoT-based information collecting and selecting, and negatively impacted by IoT-based information sharing</li> </ul>                                                                                                                                                                                                                   | 2     | 3       |

|                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                               |   |   |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|
| Objective 3. To identify the impact of the key factors on supply chain performance after implementing IoT applications in the FMCG supply chain.                                                         | • Demonstrates that environmental complexity and richness in environmental uncertainty and the bullwhip effect in industry uncertainty increase information processing needs in supply chain management                                                                                                                       | 2 | 3 |
|                                                                                                                                                                                                          | • Explains that the alignment between IoT-based information integration and decision-making uncertainty is in the interactions between the improvement of information accuracy, quality, and efficiency and the difficulties caused by environmental complexity, richness, and bullwhip effect in decision-making uncertainty | 2 | 3 |
|                                                                                                                                                                                                          | • Enriches the theory-based relational framework by providing key factors in decision-making uncertainty and IoT-based information integration                                                                                                                                                                                | 2 | 3 |
|                                                                                                                                                                                                          | • Highlights the importance of the alignment between information integration and decision-making uncertainty on supply chain performance                                                                                                                                                                                      | 2 | 3 |
|                                                                                                                                                                                                          | • Points out that the alignment between decision-making uncertainty and information integration is especially highly related to the improvement of management cost and asset utilisation in supply chain cost and to response speed, product flexibility and efficiency in production operation                               | 2 | 3 |
| Objective 4. To evaluate the key factors and interactions in the alignment between information integration and decision-making uncertainty after implementing IoT applications in the FMCG supply chain. | • Enriches the theory-based relational framework by providing key factors in supply chain management influenced by IoT-based information integration and decision-making uncertainty                                                                                                                                          | 2 | 3 |
|                                                                                                                                                                                                          | • Verifies that the improvement of information accuracy, quality, and efficiency are key factors for IoT-based information integration                                                                                                                                                                                        | 3 | 4 |
|                                                                                                                                                                                                          | • Verifies that environmental complexity, richness, and bullwhip effect are key factors for IoT-based information integration                                                                                                                                                                                                 | 3 | 4 |
|                                                                                                                                                                                                          | • Verifies that management cost reduction, asset utilisation improvement, and increasing working capital in supply chain cost and response speed, flexibility, and operation processing in production operations are key factors for supply chain performance                                                                 | 3 | 4 |

|                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                    |   |   |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|
| Objective 5. To assess the interactions between IoT-based information integration, decision-making uncertainty, and supply chain performance based on the identified factors. | <ul style="list-style-type: none"> <li>Verifies that the alignment between information integration and decision-making uncertainty are the interactions between information accuracy and environmental complexity, the interaction between information accuracy and environmental richness, the interaction between information quality and the bullwhip effect, and the interaction between information efficiency and bullwhip effect</li> </ul> | 3 | 4 |
|                                                                                                                                                                               | <ul style="list-style-type: none"> <li>Proposes that the implementation of IoT-based information integration has a significant, positive direct impact on supply chain performance</li> </ul>                                                                                                                                                                                                                                                      | 3 | 4 |
|                                                                                                                                                                               | <ul style="list-style-type: none"> <li>Proposes that decision-making uncertainty has a significant negative direct impact on supply chain performance</li> </ul>                                                                                                                                                                                                                                                                                   | 3 | 4 |
|                                                                                                                                                                               | <ul style="list-style-type: none"> <li>Proposes that the alignment has a significant positive direct impact on supply chain performance</li> </ul>                                                                                                                                                                                                                                                                                                 | 3 | 4 |
|                                                                                                                                                                               | <ul style="list-style-type: none"> <li>Identifies the partial mediating role of alignment in the relationships among IoT-based information integration, decision-making uncertainty, and supply chain performance</li> </ul>                                                                                                                                                                                                                       | 3 | 4 |

**Table 5-1. Mapping of key findings and research objectives**

## **5.2 Contributions**

### **5.2.1 Theoretical Contribution**

This research makes three key theoretical contributions to the body of literature on information integration, decision-making uncertainty, and supply chain performance.

Firstly, this thesis is the first empirical study to illustrate and evaluate detailed interactions in the relationship between information integration and decision-making uncertainty, providing empirical evidence to support the discussion of previous studies.

Paper 1 applies IPT to help understand the relationship between information integration and decision-making uncertainty, then a theme-based classification of information integration and decision-making uncertainty based on the analysis of literature is provided to develop an IPT-based relational framework (Figure 2-1). This theory-based relational framework supports previous studies on the relationship between information integration and decision-making uncertainty (Gao et al., 2005; Sniazhko, 2019; Wu et al., 2019) and clearly describes that relationship and the role of ICT in it.

Paper 2 (Chapter 3) conducts a multiple-case study to elaborate the relational framework developed in Paper 1 (Chapter 2). The theory-based relational framework in Paper 1 (Chapter 2) is enriched by embedding the implementation processes of IoT applications on information integration, the key factors in information integration and decision-making uncertainty, and the aspects of supply chain performance influenced by the alignment between information integration and decision-making uncertainty. This study thereby empirically supports the extant research (Ben-Daya et al., 2017; Birkel and Hartmann, 2019). These studies focus on the technical improvement IoT applications provide in information integration. Paper 2 introduces the IoT-based information integration's impact on supply chain performance and decision-making uncertainty and extends the analysis to a supply chain perspective.

Paper 3 (Chapter 4) conducts a survey-based PLS-SEM study to empirically examine the enriched relational framework developed in Paper 2 (Chapter 3). The alignment between information integration and decision-making uncertainty is visualised based on the identified interactions between the key

factors of decision-making uncertainty and IoT-based information integration identified in Paper 2 (Chapter 3). Five of the nine interactions between the key factors in the alignment between IoT-based information integration and decision-making uncertainty are verified. Previous studies have demonstrated the alignment between decision-making uncertainty and information integration and proposed certain theoretical associations regarding how they interact (Nagarajan et al., 2013; Singh and Garg, 2015; James and George, 2018). However, no empirical evidence is provided.

Based on the empirical analysis and synthesis in Papers 2 and 3, the theory-based relational framework is elaborated and refined by identifying the key factors in decision-making uncertainty, information integration, and supply chain performance. To the best of the author's knowledge, this research is the first empirical study to explain the detailed interactions in the relationship between information integration and decision-making uncertainty from a supply chain view. This study proposes elaborated relational frameworks that illustrate the alignment between IoT-based information integration and decision-making uncertainty (Figure 3-4), describes the interactions in this alignment (Figure 4-5), and provides empirical evidence for these relationships. The framework can help academics to better understand the interaction between information integration and decision-making uncertainty and the role of the IoT in this relationship. In doing this, this thesis also addresses the role of IoT applications in the relationship between decision-making uncertainty and information integration, which is proposed but not well discussed by previous studies (Rymaszewska et al., 2017; Rejeb et al., 2019).

Secondly, previous studies have focussed on the direct impact of information integration on supply chain performance and how decision-making uncertainty changes the impacts (Chen, 2014; Gao, 2017; Zimmermann et al., 2020). However, none have emphasised the important role of the alignment between information integration and decision-making uncertainty in impacting supply chain performance, nor the direct impact of decision-making uncertainty on supply chain performance. By contrast, this thesis demonstrates the role of the alignment between decision-making uncertainty and IoT-based information integration on supply chain performance. It proposes that the direct impact of decision-making uncertainty should be considered with the IPT-based theoretical lens in any study of the relationship between information integration and decision-making uncertainty.

Paper 1 (Chapter 2) develops the concept of fit in IPT with the evidence in the literature and proposes that there is an alignment between decision-making uncertainty and information integration. This finding supports previous research, which indicates that supply chain stakeholders must ensure that the level of information integration fits with the decision-making uncertainty experienced to improve their performance (Premkumar et al., 2005; Cegielski et al., 2012). Paper 2 (Chapter 3) further demonstrates the importance of the alignment on supply chain performance and provides empirical evidence which identifies that the alignment impacts supply chain costs and production operations in supply chain performance. This finding provides empirical support for previous conceptual studies which propose that the alignment between information integration and decision-making uncertainty is important and create a balance between information processing capability and information processing need, improving supply chain performance (e.g., Wong et al., 2015; Sacristán-Díaz et al., 2018).

Paper 2 (Chapter 3) also analyses the role of decision-making uncertainty in supply chain management. It finds that environmental and industry uncertainty closely relates to information processing and supply chain performance. When decision-making uncertainty emerges, supply chain stakeholders experience difficulty evaluating the outcome of their decisions to preserve or improve supply chain performance. It follows that environmental complexity and richness are fundamental problems that lead to unexpected changes in supply chain management; the bullwhip effect creates demand distortion and increases the pressure on inventory management (Gao et al., 2005; Plötner et al., 2013; Chen, 2014). In addition, the analysis reveals that environmental richness and supply chain structure in environmental uncertainty are not concerns for supply chain stakeholders when the need for information sharing is low. This point has not yet been made in extant literature.

Paper 3 (Chapter 4) verifies the key factors in supply chain costs and production operations and evaluates the direct impact of the alignment on supply chain performance. As in the extant literature (Qrunfleh and Tarafdar, 2014; Yuen and Thai, 2017), the mediating role of the alignment is identified. Nevertheless, different from previous studies, the analysis results show that the alignment has two different mediation effects: a complementary mediator in the relationship between IoT-based information integration and supply chain performance and a competitive mediator in the relationship between decision-making uncertainty and supply chain performance. Consequently, this thesis

extends previous knowledge by proposing that the alignment partially mediates the relationships among decision-making uncertainty, IoT-based information integration, and supply chain performance. The direct effects of decision-making uncertainty to supply chain management are also analysed in Paper 3. The result shows that the direct impacts of decision-making uncertainty on supply chain performance is significant. This finding demonstrates that decision-making uncertainty and IoT-based information integration impact supply chain performance through their alignment and directly impact supply chain performance through the changes in key factors. Consequently, a revised theoretical lens based on IPT is proposed for future research, addressing the direct impact of decision-making uncertainty.

### **5.2.2 Methodological Support**

This thesis provides an example of the rigorous methodology for studying an emerging phenomenon's impact on the existing relationship between two variables and the resulting impact on the third variable. Specifically, this study considers the implementation of IoT applications as an emerging phenomenon, exploring its impact on the interactions in the relationship between information integration and decision-making uncertainty as well as its specific impacts on supply chain performance. The thesis first qualitatively interprets the key factors of information integration, decision-making uncertainty, and supply chain performance and then quantitatively examines their interactions. The analysis results illustrate that the sequential exploratory research design (Saunders et al., 2009) is validated for supply chain management research to study emerging phenomena.

### **5.2.3 Practical Contribution**

This research presents important practical contributions by offering the potential to develop tools or frameworks for supply chain managers. First, the findings illustrate the real potential of IoT applications beyond data sharing and data transfer. For instance, the findings indicate the potential for supply chain stakeholders to reduce supply chain management costs after implementing IoT applications in the information-sharing process. Based on this finding, supply chain managers can make more-accurate predictions concerning implementation outcomes. Furthermore, the impact of specific ICT implementation on the relationship between information integration and decision-making uncertainty is well explained in this thesis. With these identified impacts of each implementation, an evaluation tool can be developed based on

the findings for supply chain managers. This tool would help select the appropriate technology to support the company's information integration and to obtain a competitive advantage at the supply chain level.

Second, this study's results can guide the development of information integration implementation tools. Supply chain managers should be fully aware of the importance of the alignment in supply chain management when implementing IoT applications (de Vass et al., 2018; Kumar et al., 2020). The findings emphasise that implementing IoT applications can positively impact supply chain performance when commensurate with the level of decision uncertainty suffered by supply chain stakeholders. The interactions of key factors in IoT-based information integration and decision-making uncertainty are also provided. Only the environmental complexity, environmental richness, and bullwhip effect in decision-making uncertainty interact with IoT-based information integration. Thus, an evaluation form of decision-making uncertainty in the supply chain can be developed for supply chain managers to implement IoT applications. For instance, when supply chain stakeholders perceive decision-making uncertainty, such as the bullwhip effect and environmental complexity, the implementation of IoT applications is a promising solution. With respect to the issues caused by supply chain structure or firm uncertainty, the implementation of IoT applications is not the proper approach. Moreover, a step-by-step (information collecting → selecting → sharing → decision-making support) implementation process is empirically verified based on the qualitative analysis, highly recommended for supply chain managers to follow.

Third, the impact on supply chain performance is well discussed. The findings also identify the key factors of information integration, decision-making uncertainty, and supply chain performance impacted by the implementation of IoT applications. Supply chain management can use these key factors to create their own key performance indicators (KPIs) and to develop a supply chain performance-oriented evaluation system to forecast the outcomes of implementing IoT applications. The system can forecast what can be achieved in supply chain performance after implementing IoT applications. For instance, decision-making uncertainty negatively influences supply chain management (Wangphanich et al., 2010). With the system, supply chain stakeholders can identify the extent of issues related to decision-making uncertainty in their supply chain, link the issues to the impact of IoT application implementation in

different information integration processes, and finally predict the resulting impact on supply chain performance before implementing IoT applications.

Finally, according to the findings in this thesis, the alignment between decision-making uncertainty and IoT-based information integration positively impacts supply chain costs and production operations in supply chain performance. In practice, supply chain managers may resist the adoption of new integration implementation in the supply chain due to a lack of ability to forecast the short-term benefits (Lewis and Harvey, 2001). This research indicates that the initial implementation of IoT applications cannot solve the problems caused by environmental uncertainty, which is critical to improving financial performance, so it cannot bring short-term economic benefits to supply chain stakeholders. The practical benefits are highlighted by demonstrating the implementation of IoT is at an early stage and developing an evaluation system, such that supply chain stakeholders' doubts about implementing IoT applications can be removed. In addition, product quality is not included in the supply chain performance indicators that are impacted by the alignment. Supply chain managers should note this when implementing IoT applications in information integration.

### **5.3 Limitations**

This research faces certain limitations. First, the SLR targets peer-reviewed journal papers to ensure the papers' quality. Some good conference papers and theses relevant to the research topic might not be selected. Moreover, the SLR uses three databases; papers not included in these databases may be omitted.

Second, the empirical works (Chapters 3 and 4) focus on only the fast fashion industry in China. However, most stakeholders in the fast fashion supply chain are in the initial stage of implementing IoT applications. The implementation of IoT applications may be more advanced in other industries, which would reduce the generalisability of this study's findings. However, the extant research demonstrates that the implementation of IoT applications in supply chain management remains nascent (Lampropoulos et al., 2019; Lu, 2021), making this issue less urgent.

Third, this research assumes that IoT-based information integration aligns with decision-making uncertainty in the supply chain and demonstrates that supply chain performance is improved due to this alignment. No research on the

situation yet contradicts this assumption. This constraint may limit the generalisability of the findings to other supply chains with different contexts, such as the stakeholders who, in an environment with high decision-making uncertainty, have not yet implemented IoT applications.

Fourth, within and cross-case analyses are conducted for the multiple-case study in Chapter 3 to provide a theoretical generalisation of findings (Yin, 2009). However, the cases in the study were purposively chosen, which may restrict the validity of the findings. Additionally, this study is confined to the examination of fast fashion supply chains in China, and all the interviews were conducted in Chinese. Hence, care is necessary in interpreting the findings in English.

## **5.4 Future Research Directions**

Following the results of this study, several promising future research directions are recommended. First, the IoT is selected as the representative of ICT in the empirical studies (Chapters 3 and 4). As proposed in the conceptual framework in the SLR, other Industry 4.0 technologies might also support information integration. For instance, big data analytics facilitates the alignment of information and improves demand forecasting accuracy (Niu and Zou, 2017; Rejeb et al., 2019; Hsu et al., 2021), increasing the information processing capability and simplifying the application of integration and collaboration approaches for supply chain stakeholders (Chen et al., 2017; Kache and Seuring, 2017). Similarly, the blockchain can increase information transparency and enhance information-sharing security between supply chain stakeholders (Li et al., 2020; Vu et al., 2021). Future studies should investigate the influence of advanced technology applications in Industry 4.0 (e.g., big data or the blockchain) on the relationship between information integration and decision-making uncertainty.

Second, in the empirical findings, certain factors of information integration and decision-making uncertainty are found to be irrelevant to the implementation of IoT applications. For instance, the findings suggest that information security and technology acceptance (firm uncertainty) do not show apparent impacts in the alignment between information integration and decision-making uncertainty. However, there is evidence that firm uncertainty may have some effect on supply chain performance. Scholars propose that the level of technology acceptance increases with the maturity and universality of the technology (Bienstock and Royne, 2010; Kros et al., 2011). With high

acceptance of technology, firms introduce new technologies into their management processes to reduce uncertainty in operations (Patnayakuni et al., 2006; Chang and Sanchez-Loor, 2020; Li et al., 2020). Therefore, a worthy topic for future studies is to investigate the role of firm uncertainty on supply chain performance after IoT applications have been widely implemented.

Similarly, the impact of IoT-based information integration on information security presents a dilemma. This study proposes that the implementation in the information-sharing process negatively impacts information security, whereas the implementation in the information collecting and selecting process positively impacts information security. To explicitly demonstrate this link, further explanation and empirical evidence are required. The extant literature also argues that IoT applications' drawbacks must be carefully assessed when implemented, especially the risk in information security (Boos et al., 2013; Mbhele and Phiri, 2014). Therefore, it is promising to evaluate the impact of IoT-based information integration on information security.

Third, this study explains the impact of information integration and decision-making uncertainty on supply chain performance. Evidence derived from the literature, with both qualitative and quantitative data, indicates that the relationship between information integration implementation and decision-making uncertainty can positively impact supply chain performance after implementing IoT applications. Despite the findings in this research, some scholars have illustrated that the relationship between information integration implementation and decision-making uncertainty can also impact the relationship between supply chain stakeholders. For instance, the collaboration improved by information integration enhances the relationship between supply chain stakeholders (Xu et al., 2015; Salam, 2017). Therefore, future research should investigate the resultant impact of the relationship between information integration implementation and decision-making uncertainty on the relationship between supply chain stakeholders.

Fourth, some of the limitations of the empirical works can be addressed by future research. The study focusses on the typical supply chain model in the fast fashion industry, but the implementation stage of IoT applications might differ in other industries. Ergo, future research studies in other industries (e.g., food industry) are expected to generate different findings or to enhance the external validity of this research. It would also be worth focussing on a single implementation stage and extending the findings of this research. Moreover, this study proposes that the existing alignment between IoT-based information

integration and decision-making uncertainty in the supply chain improves supply chain performance. Future research can use empirical data to investigate whether IoT-based information integration aligns with decision-making uncertainty, what happens to their interactions if not, and the resulting impacts on supply chain performance.

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## APPENDICES

The appendices for Chapter 2, some detailed analysis results and the data collection method used for Chapter 3 and for are described detailly in this section.

### Appendix A Appendices of Chapter 2

#### A.1 Relevance criteria for screening

Table A- 1. Relevance criteria

| Criteria                                                                             | Rationale                                                                                                                                                                                   |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Inclusion                                                                            |                                                                                                                                                                                             |
| peer-reviewed journal articles                                                       | Focusing on peer reviewed journal articles for academic rigor and quality.                                                                                                                  |
| Publications since 2000                                                              | There is limited information integration research in supply chain management before this time.                                                                                              |
| Supply chain or organization level studies                                           | This study focusses on decision making in supply chain management, not focus on individual behaviour                                                                                        |
| Theoretical, empirical studies and review papers, either qualitative or quantitative | Different approaches have contributed to the research areas.                                                                                                                                |
| The papers discuss fast-moving consumer goods industry                               | The articles discuss FMCG supply chain or uses the supply chain model that suitable for FMCG supply chain is included.                                                                      |
| Exclusions                                                                           |                                                                                                                                                                                             |
| Individual decision-making behaviour                                                 | The focus of the study is on supply chain level                                                                                                                                             |
| Natural sciences (related to individual or human)                                    | The discipline of this review is management that based on social science disciplines; therefore, papers focus on human behaviour (e.g. psychological or biological behaviour) are excluded. |
| Computer sciences and engineering                                                    | The research interest is in the application of technologies to management problems not the development of the technologies themselves.                                                      |

## A.2 Quality assessment criteria for screening

**Table A- 2. Quality assessment criteria**

| <b>Quality assessment criteria</b>           |                                                                           |                                                                                                  |                                                                                                     |                                                                                         |                                                          |
|----------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|----------------------------------------------------------|
| Element                                      | Level                                                                     |                                                                                                  |                                                                                                     |                                                                                         |                                                          |
|                                              | 0 Absence                                                                 | 1 Low                                                                                            | 2 Medium                                                                                            | 3 High                                                                                  | Not applicable                                           |
| 1. Theory robustness                         | The article does not provide enough information to assess this criterion. | Theoretical development is inadequate.                                                           | Theoretical development is acceptable.                                                              | Strong theoretical basis.                                                               | This element is not applicable to the document or study  |
| 2. Implication for practice                  | The article does not provide enough information to assess this criterion. | Very difficult to implement the research ideas. Not relevant for practitioners or professionals. | There is a potential for implementing the research ideas but may need minor adjustments.            | Significant benefit may be obtained if the ideas being discussed are put into practice. | This element is not applicable to the document or study  |
| 3. Methodology and data supporting arguments | The article does not provide enough information to assess this criterion. | Poor research design; Inappropriate method; Data inaccuracy and not related.                     | Justified research design; Acceptable method; Data are related to the arguments but have some gaps. | Excellent research design; Good method; Data strongly supports arguments.               | This element is not applicable to the document or study. |
| 4. Result                                    | The article does not provide enough information to assess this criterion. | No accurate and clear result is presented, and the result does not match the method.             | Appropriate result is presented; the result match the method.                                       | Accurate and clear result is presented; the result match the method rigorously.         | This element is not applicable to the document or study. |

|                    |                                                                           |                                                                                                                      |                                                                                                        |                                                                                                     |                                                          |
|--------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| 5.<br>Conclusion   | The article does not provide enough information to assess this criterion. | The conclusions do not discuss the findings logically; No limitation or implication of future research are proposed. | Appropriate discussion of findings; The limitation or the implication of future research are proposed. | Logical discussion of findings; The limitation and the implication of future research are proposed. | This element is not applicable to the document or study. |
| 6.<br>Contribution | The article does not provide enough information to assess this criterion. | The paper adds little to the body of knowledge in this area.                                                         | Contribution to knowledge is ordinary.                                                                 | Significant addition to current knowledge; fill an important theory gap.                            | This element is not applicable to the document or study. |

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**Table A- 3. Distribution of Papers in Journals**

| <b>List of journals</b>                                               | <b>Number</b> | <b>AJG<br/>Ranking</b> |
|-----------------------------------------------------------------------|---------------|------------------------|
| International Journal of Production Economics                         | 10            | 3                      |
| International Journal of Physical Distribution & Logistics Management | 7             | 2                      |
| Sustainability                                                        | 5             | 2                      |
| European Journal of Operational Research                              | 4             | 4                      |
| International Journal of Production Research                          | 4             | 3                      |
| Benchmarking                                                          | 4             | 1                      |
| Production and Operations Management                                  | 3             | 4                      |
| Production Planning and Control                                       | 3             | 3                      |
| Journal of Operations Management                                      | 2             | 4                      |
| Decision Support Systems                                              | 2             | 3                      |
| Omega-International Journal of Management Science                     | 2             | 3                      |
| Supply Chain Management                                               | 2             | 3                      |
| Technological Forecasting and Social Change                           | 2             | 3                      |
| Computers and Industrial Engineering                                  | 2             | 2                      |
| International Transactions in Operational Research                    | 2             | 2                      |
| Journal of Construction Engineering and Management                    | 2             | 1                      |
| Academy of Management Journal                                         | 1             | 4                      |
| Journal of Management Information Systems                             | 1             | 4                      |
| Management Science                                                    | 1             | 4                      |
| Marketing Science                                                     | 1             | 4                      |
| Operational Research                                                  | 1             | 4                      |
| Annals of Operations Research                                         | 1             | 3                      |

|                                                                 |   |   |
|-----------------------------------------------------------------|---|---|
| Decision Sciences                                               | 1 | 3 |
| Industrial Marketing Management                                 | 1 | 3 |
| Journal of Business Research                                    | 1 | 3 |
| Naval Research Logistics                                        | 1 | 3 |
| Applied Sciences                                                | 1 | 2 |
| Behaviour & Information Technology                              | 1 | 2 |
| Business Process Management Journal                             | 1 | 2 |
| Future Internet                                                 | 1 | 2 |
| Industrial Management & Data Systems                            | 1 | 2 |
| International Journal of Logistics Management                   | 1 | 2 |
| International Journal of Logistics-Research and Applications    | 1 | 2 |
| International Journal of Operations & Production Management     | 1 | 2 |
| Journal of Construction Engineering and Management              | 1 | 2 |
| Resources, Conservation and Recycling                           | 1 | 2 |
| Risk Analysis                                                   | 1 | 2 |
| British Food Journal                                            | 1 | 1 |
| Information Development                                         | 1 | 1 |
| Journal of Industry Competition & Trade                         | 1 | 1 |
| Journal of Modelling in Management                              | 1 | 1 |
| Journal of Systems Science and Systems Engineering              | 1 | 1 |
| Journal of Theoretical and Applied Electronic Commerce Research | 1 | 1 |
| Journal of Transport and Supply Chain Management                | 1 | 1 |
| Mathematics                                                     | 1 | 1 |
| Mediterranean Journal of Social Sciences                        | 1 | 1 |

|                                              |   |   |
|----------------------------------------------|---|---|
| RAIRO: Recherche Opérationnelle              | 1 | 1 |
| South African Journal of Business Management | 1 | 1 |

## Appendix B Appendices of Chapter 3

### B.1 Semi Structured Interview Guideline Pilot Test Results

Before the pilot test, the interview guideline was review by two academic experts. After revising the guideline with their comments, five industrial practitioners are invited to further test the of the intelligibility of the questions in the guideline. The target experts and practitioners and their introductions are shown in Table B- 1

**Table B- 1. Lists of the participant for pilot run**

| Participant    | Introduction                                                                                                                                                                                                                                       |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Expert 1       | Expert 1 is interested in supply chain operations, especially risk and resilience issues and the implementation of Industry 4.0 technologies in the supply chain.                                                                                  |
| Expert 2       | Expert 2 focuses on a wide interest in issues in supply chains from strategic network optimisation to detailed simulations of each part of the supply chain, such as storage, logistic, and purchase etc.                                          |
| Practitioner 1 | A senior manager in a apparel manufacturer, in charge of the supply of materials related to the order. The apparel manufacturer produces all kinds of clothing of major brands (sportswear, casual wear, functional clothing).                     |
| Practitioner 2 | A department leader in a fabric supplier, is responsible for the formulation of production plans, communication with various factories, and product quality control. The fabric supplier mainly produces knitted fabrics.                          |
| Practitioner 3 | A warehousing plan director of a multinational clothing company, take charge of the finished product and inventory management. The multinational clothing company is a professional sports brand, design and sale of various sportswear and shoes. |
| Practitioner 4 | A CEO of an apparel company. The company integrates design, production and sales, and the main products are women's fashion and backpacks.                                                                                                         |

|                |                                                                                                                                                                              |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Practitioner 5 | A development director of an apparel company, the main work are product development and customer analysis. The company's main products are men's fashion backpacks and shoes |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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Each participant was contacted through phone call and the one-page research introduction (cover letter) was sent to them via chat app. The pilot test was conducted by video call. The comments and suggestions from them are listed in Table B- 2.

**Table B- 2. Comments from the experts**

| Participant | Comments and suggestions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Expert 1    | <p>Part 1, Question one needs breaking down - I would suggest asking about their understanding, then the problems addressed using IOT then possibly following up on the technologies. I would keep this broad and general about their views not their experience of application</p> <p>Part 2, Question one assumes everyone who you talk to will have implemented IoT - is this always true?</p> <p>Part 3, Question one is better to ask them what the most important/relevant uncertainties for their firms are. Other than in the supply chain.</p> <p>Part 4, You need to link this to the ideas you have already discussed explicitly. You have talked about DMU so in doing that you probably need to talk about the requirements for this explicitly and you have talked about requirements for information sharing and the role of IoT - so now you need to talk about whether in the view of the interviewee do these align.</p> |
| Expert 2    | <p>Part 2, Ask Question one in a more general terms such as how they manage information sharing then if they have implemented IOT dig into what they did before and what they do now.</p> <p>Part 3, Question one is too big, need to draw this question out further - again is it not related to the adoption of the technology directly rather than the link to decision-making uncertainty?</p> <p>Part 4, the follow up questions for Question one needs some examples to make interviewees better understand the meaning.</p>                                                                                                                                                                                                                                                                                                                                                                                                         |

|                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Practitioner 1 | <p>Part 1, You are making an assumption that your interviewees will know what IoT is - is this realistic?</p> <p>Part 2, some of the questions are far too complicated - you need to break it down.</p> <p>Part 3, don't know what you mean here - probably need contextual examples.</p> <p>Part 4, too complicated, questions are hard to understand.</p>                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Practitioner 2 | <p>Some questions need very careful wording</p> <p>There are some leading questions and - you need to rephrase them - I suspect respondents will answer yes or say they don't understand what you mean. How else might you get the information you need here?</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Practitioner 3 | <p>Part 1, it is better to talk about this in more general terms first - you might want to explore more general examples. Then have a second main question asking about their firm and their experience and plans.</p> <p>Part 2, it is better to be specific and talk about each process/technology in turn and talk about the impact on information access, retrieval etc rather than for IoT as a whole.</p> <p>Part 4, I see why you want to ask these questions - but I think you will need to relate these to what you have learnt in the interview - so by this stage you should know about the DMU situation and the IOT implementation status of the company - so using the examples that they have given you will need to explore this match with your interviewees.</p> |
| Practitioner 4 | <p>Part 2, it is better to be targeted here and talk about the IoT applications already discussed and their impact directly on decision-making uncertainty - specific examples will be much more powerful in your analysis</p> <p>Part 4, suggest to relate these to what you have learnt in the interview - so using the examples that they have given you will need to explore this match with your interviewees.</p>                                                                                                                                                                                                                                                                                                                                                            |
| Practitioner 5 | <p>Overall, the guideline is too academic, need to carefully think how to pose the questions in practitioners' language.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

---

The following actions were taken to revise the survey:

- Take more times to explain the context to the practitioners, make sure they understand the explanation in each part and understand what the questions ask about.

- Carefully checked all the questions, change the ones that looks like a leading question.
- In part one, Question one is more towards the practitioners' experience, then detailed follow up questions are ask based on their answer.
- In part two, change the focus to information integration and what IoT brings to information integration.
- In part three, delete the big questions and use separate questions to ask the interviewees' idea about decision-making uncertainty and how it impacts supply chain management.
- In part four, the questions are asked based on the examples given by the interviewees, and discussion are mainly in what they think the alignment is and how important it is.

## **B.2 Semi Structured Interview Guide before Pilot Test**

### **Internet of Things implementation in the fast fashion industry**



Dear Sir or Madam,

My name is Xue Yufei, and I am a PhD candidate from the Centre for Logistics, Procurement and Supply Chain Management, Cranfield University, UK.

Together with Dr. Nicky Yates ([nicky.yates@cranfield.ac.uk](mailto:nicky.yates@cranfield.ac.uk)) and Dr. Abhijeet Ghadge ([abhijeet.ghadge@cranfield.ac.uk](mailto:abhijeet.ghadge@cranfield.ac.uk)), I am currently researching on the application of Internet of Things technology in textile and apparel supply chain management. Given your expertise in this area, I would like to invite you to participate in this study.

In recent years, the Internet of Things technology has been applied to our lives. Internet of Things effectively promotes the intellectual development of all aspects, such as industry, agriculture, environment, transportation, logistics, security, and other infrastructure fields, making the limited resources more rational use and allocation, thus improving the efficiency and efficiency of the industry. However, the implementation of Internet of Things technology in supply chain management is still in the stage of development, and how to customize the application of

Internet of Things technology according to the different characteristics of each enterprise is still in the exploratory stage. Therefore, we hope to clarify the specific impact of the Internet of Things technology on supply chain management by investigating and researching the application of Internet of Things technology in enterprises.

Through our understanding, your company has been carrying out the application of Internet of Things technology. Your professional experience will help answer some of the research questions raised in this study. Therefore, I would like to discuss with you and listen to your views on the Internet of Things technology from a practical application perspective.

Best regards,

Yufei XUE

PhD student,

Cranfield School of Management (SoM)

Cranfield, Bedfordshire, MK43 0AL, United Kingdom

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**Table B- 3. Interview guideline before pilot run**

| Initial interview guideline                                                                                                                                                         |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Part 1 IoT applications in the supply chain</b>                                                                                                                                  |
| <i>We define Internet of Things (IoT) as the devices, technologies, hardware, and software that used to support information collecting, selecting and sharing in supply chains)</i> |
| Please think about your experiences in implementing IoT in the supply chain                                                                                                         |
| <b>Main question 1</b>                                                                                                                                                              |
| From your point of view, what are the IoT applications in the supply chain?                                                                                                         |
| <b>Follow-up questions</b>                                                                                                                                                          |
| What issues can the IoT applications solve in the supply chain?                                                                                                                     |
| What are the technologies used in IoT application?                                                                                                                                  |
| <b>Main question 2</b>                                                                                                                                                              |
| Can you provide some examples of the IoT applications you've seen or known in the industry?                                                                                         |

***Follow-up questions***

Can you provide some examples of the IoT applications that your firm/partner implements or plans to implement?

What benefits can these IoT applications bring to your firm?

**Part 2 Measurement of information integration in supply chain**

*We define information as the data (e.g., orders, inventory details, bills of materials, reports of machines) and other materials (emails, dialog, video, etc.) that are processed and exchanged by supply chain stakeholders.*

***Main question 1***

How does your firm manage information processing?

***Follow-up questions***

Regarding information collecting process, how does your firm/partner make the sources of information available?

Regarding information selecting process, how is information retrieved?

How does your firm share information with partners?

***Main question 2***

Have you implemented IoT in these processes?

***Follow-up questions 2-1***

If so, in which processes you implement or plan to implement IoT application?

What technologies you select or plan to select for IoT applications in these processes?

What information you share or plan to share with the IoT applications?

How did you realise these processes before, when did not implement IoT?

***Follow-up questions 2-2***

If not, will you implement IoT in these processes?

Yes

In which processes you implement or plan to implement IoT application?

What technologies you select or plan to select for IoT applications in these processes?

What information you share or plan to share with the IoT applications?

No

Why does your firm not plan to implement IoT application in these processes?

**Main question 3**

What are the benefits and drawbacks of IoT applications on this process do you see for your firm and the whole supply chain?

**Follow-up questions**

From your point of view, in which process and how does the technology you mentioned above impact on the difficulty of access to information?

From your point of view, in which process and how does the technology you mentioned above impact on the time it takes to produce and retrieve information?

From your point of view, in which process and how does the technology you mentioned above impact on the excellence, value, conformance of the information?

From your point of view, in which process and how does the technology you mentioned above impact on the error/bias and the correctness of the information?

From your point of view, in which process and how does the technology you mentioned above impact on the capability of information and information systems protection (the ability to detect, document, and counter the threats of unauthorized access, use, disclosure, disruption, modification or destruction)?

**Part 3 Measurement of decision-making uncertainties in supply chain**

*We define decision-making uncertainty as: (1) The unexpected changes in the business environment. (2) The uncertainty which occurs during the interaction between supply chain stakeholders, such as demand distortion and unpredictable competition. (3) The uncertainty generated in a firm's operational processes, for instance, the uncertainty in production caused by technology implementation.*

**Main question 1**

What are the most important/relevant uncertainties for your firm before and now?

**Follow-up questions**

Which one impact your firm the most seriously before implement IoT applications?

Which one impact the supply chain the most seriously before implement IoT applications?

Which one impact your firm the most seriously after implement IoT applications?

Which one impact the supply chain the most seriously after implement IoT applications?

### **Main question 2**

What impact do IoT applications have on decision-making uncertainty for your firm and the whole supply chain?

### **Follow-up questions**

How do they impact on the unexpected changes in the business environment?

How do they impact on the uncertainty which occurs during the interaction between your firm and partners?

How do they impact on the uncertainty generated in your firm's operational processes?

### **Part 4 The alignment of fit between IoT-based information integration and decision-making uncertainty**

***We define the alignment of fit as the degree to which the improvement of information management process (the methods or technologies used to share information) is consistent with the requirement of information (the decision-making uncertainties) in the supply chain***

### **Main question**

Do you think the information management process need to align with the requirement of information in your company?

### **Follow-up questions**

Yes

Do you think the alignment between the information management process and the requirement of information sharing created by decision-making uncertainty in your company improved after implementing IoT applications?

No

Why this alignment is not necessary?

### **Main question**

Will this alignment have impact on the supply chain performance? For instance, the complication of decision-making process determines the requirement for accurate and timely information, IoT application fulfil this requirement and support decision-making process, consequently, improve work efficiency.

### **Follow-up questions**

If yes, what is the impact?

If not, why this alignment has no impact?

Opportunity for comments and further information or questions.

---

### **B.3 The Revised Semi Structured Interview Guide after Pilot Test**

#### **Internet of Things implementation in the fast fashion industry**



Dear Sir or Madam,

My name is Xue Yufei, and I am a PhD candidate from the Centre for Logistics, Procurement and Supply Chain Management, Cranfield University, UK.

Together with Dr. Nicky Yates ([nicky.yates@cranfield.ac.uk](mailto:nicky.yates@cranfield.ac.uk)) and Dr. Abhijeet Ghadge ([abhijeet.ghadge@cranfield.ac.uk](mailto:abhijeet.ghadge@cranfield.ac.uk)), I am currently researching on the application of Internet of Things technology in textile and apparel supply chain management. Given your expertise in this area, I would like to invite you to participate in this study.

In recent years, the Internet of Things technology has been applied to our lives. Internet of Things effectively promotes the intellectual development of all aspects, such as industry, agriculture, environment, transportation, logistics, security, and other infrastructure fields, making the limited resources more rational use and allocation, thus improving the efficiency and efficiency of the industry. However, the implementation of Internet of Things technology in supply chain management is still in the stage of development, and how to customize the application of Internet of Things technology according to the different characteristics of each enterprise is still in the exploratory stage. Therefore, we hope to clarify the specific impact of the Internet of Things technology on supply chain management by investigating and researching the application of Internet of Things technology in enterprises.

Through our understanding, your company has been carrying out the application of Internet of Things technology. Your professional experience will help answer some of the research questions raised in this study. Therefore, I would like to discuss with you and listen to your views on the Internet of Things technology from a practical application perspective.

Best regards,

Yufei XUE

PhD student,

Cranfield School of Management (SoM)

Cranfield, Bedfordshire, MK43 0AL, United Kingdom

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**Table B- 4. Interview guideline after pilot run**

---

**Initial interview guideline**

---

**Part 1 IoT applications in the supply chain**

*We define Internet of Things (IoT) as the devices, technologies, hardware, and software that used to support information collecting, selecting and sharing in supply chains)*

Please think about your experiences in implementing IoT in the supply chain

**Main question 1**

From your point of view, what are the main IoT applications in the supply chain?

**Follow-up questions**

What issues can the IoT applications solve in the supply chain?

What are the technologies used in IoT application?

**Main question 2**

Can you provide some examples of the IoT applications that your firm/partner implements or plans to implement?

**Follow-up questions**

If haven't, can you provide some examples of the IoT applications you've seen or known in the industry?

**Part 2 Measurement of information integration in supply chain**

*We define information as the data (e.g., orders, inventory details, bills of materials, reports of machines) and other materials (emails, dialog, video, etc.) that are processed and exchanged by supply chain stakeholders.*

**Main question 1**

What is the information in your supply chain?

**Follow-up questions**

What is the information your firm collected during supply chain operation?

What is the information your firm selected to support decision-making?

What is the information your firm shared with partners?

**Main question 2**

How does your firm manage information in above information processing processes (information collecting/selecting/sharing)?

**Follow-up questions**

Regarding information collecting process, what are the sources of information that support supply chain operation?

Regarding information selecting process, what are the criteria for information that supporting decision-making?

How does your firm share information with partners?

**Main question 3**

Have you implemented IoT in above information processing processes (information collecting/selecting/sharing)?

**Follow-up questions 3-1**

If so, in which processes you implement or plan to implement IoT application?

What technologies you select or plan to select for IoT applications in these processes?

What information you share or plan to share with the IoT applications?

What were the drivers of adopting these technologies?

**Follow-up questions 3-2**

If not, will you implement IoT in these processes?

Yes

In which processes you implement or plan to implement IoT application?

What technologies you select or plan to select for IoT applications in these processes?

What information you share or plan to share by the IoT applications?

What are the drivers of adopting these technologies?

No

Why does your firm not plan to implement IoT application in these processes?

**Main question 4**

What are the benefits and drawbacks of IoT applications on this process do you see for your firm and the whole supply chain?

**Follow-up questions**

What are the expected benefits of these IoT applications on information processing processes, and are the expectations achieved?

What is the exact benefits bring by the technologies your mentioned above?

Despite the benefits on information processing processes, are there any other benefits?

**Part 3 Measurement of decision-making uncertainties in supply chain**

*We define decision-making uncertainty as: (1) The unexpected changes in the business environment. (2) The uncertainty which occurs during the interaction between supply chain stakeholders, such as demand distortion and unpredictable competition. (3) The uncertainty generated in a firm's operational processes, for instance, the uncertainty in production caused by technology implementation.*

**Main question 1**

What are the most important/relevant uncertainties for your firm before and now?

**Follow-up questions**

What uncertainties impact your firm the most seriously before implement IoT applications?

What uncertainties impact the supply chain the most seriously before implement IoT applications?

What uncertainties impact your firm the most seriously after implement IoT applications?

What uncertainties impact the supply chain the most seriously after implement IoT applications?

**Main question 2**

What impact do the technologies you've mentioned above have on decision-making uncertainty for your firm and the whole supply chain?

**Follow-up questions**

How do they impact on the unexpected changes in the business environment?

How do they impact on the uncertainty which occurs during the interaction between your firm and partners?

How do they impact on the uncertainty generated in your firm's operational processes?

**Part 4 The alignment of fit between IoT-based information integration and decision-making uncertainty**

*We define the alignment of fit as the degree to which the improvement of information management process (the methods or technologies used to share information) is consistent with the requirement of information (the decision making uncertainties) in the supply chain*

**Main question 1**

What is your point of view on the alignment between the information management process and the requirement of information?

**Follow-up questions**

There is an alignment

Do you think the alignment between the information management process (IoT technologies you mentioned above) and the requirement of information sharing created by decision-making uncertainty (decision-making uncertainties you mentioned above) in your company improved after implementing IoT applications?

There is not an alignment

Why this alignment is not necessary?

**Main question 2**

Will the alignment between the IoT technologies (mentioned above) and decision-making uncertainties (mentioned above) have impact on the supply chain performance?

**Follow-up questions**

If yes, what is the impact?

If not, why this alignment has no impact?

Opportunity for comments and further information or questions.

---

**B.4 Interview transcripts**

Pls see the separate document named "Interview Transcripts".

**B.5 Documents and Secondary Data**

Data from websites, new, company reports, and industrial reports are used to realise the triangulation of evidence (as shown in Table B- 5). This data is mainly qualitative. These data sources will also be used to corroborate any interview data. Since most of the organisations included in this research were small or medium companies, there was not much secondary data available. Nevertheless, the available information in each of the three cases help provided additional insight and perspective on the three perspectives of this research (decision-

making uncertainty, IoT-based information integration, and supply chain performance).

**Table B- 5. Other documentation list for Paper 2**

| Cases                                | Documentary Evidence                                                                                                                                                                                 | No. of documents |
|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| The sportswear supply chain          | Company and industrial news related to IoT applications in the supply chain, supply chain issue analysis report, company performance report                                                          | 12               |
| The women's casual wear supply chain | Company presentation related to IoT applications in the supply chain, Reports related to supply chain issues, company performance report                                                             | 8                |
| The men's fashion wear supply chain  | Company and industrial report related to IoT applications in the supply chain, internal assessments about the decision-making uncertainty's impact, company performance report, database information | 17               |

## B.6 Observations

Observations is another source of the evidence. Three companies agreed to offer the opportunity for an observation (see Table B-4). These observations were combined with interviews with the responsible managers related to supply chain. Unfortunately, none of the three companies allow photo or video record due to internal company security regulations.

**Table B- 6. Observations for Paper 2**

| Case                                 | Observation Activity                                                                                                                                                                                                    | Time | Date       |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------------|
| The sportswear supply chain          | Tour of the brand's head office in Shanghai. Observation included watching the production planning activities, control tower for connecting different manufacturers and suppliers as well as the innovation department. | 2h   | 2021/11/17 |
| The women's casual wear supply chain | Tour of one manufacturer in Shanghai. Observation included watching the assembly lines as well as the package                                                                                                           | 1.5h | 2021/12/2  |

and storage management for finished goods.

|                                     |                                                                                                                                                            |    |            |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|----|------------|
| The men's fashion wear supply chain | Tour of the warehouse centre in Suzhou. Observation included watching the auto inventory management and also the inbound and outbound logistics for goods. | 1h | 2021/12/15 |
|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|----|------------|

## B.7 Template Analysis

**Table B- 7. The a priori themes for coding system**

| Theoretical dimension                                            | Priori themes                                                                         |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| 1 Resource that improves information processing capability (RBV) | IoT applications                                                                      |
| 2 Information processing capability (IPT)                        | Information integration                                                               |
| 3 Information processing needs (IPT)                             | Decision-making uncertainty                                                           |
| 4 The concept of fit (IPT)                                       | Alignment between information integration and operational decision-making uncertainty |

**Table B- 8. The framework of initial template**

| Higher-order codes                                           | Lower-order codes                            | Sub-codes                                                              |
|--------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------------|
| IoT applications in supply chain management                  | Impact related to information integration    | Information sharing<br>Information collecting<br>Information selecting |
|                                                              | Impact irrelevant to information integration | Decision-making support                                                |
| IoT-based information integration in supply chain management | Measurement                                  | Information accuracy<br>Information quality<br>Information efficiency  |
|                                                              | Positive impact                              | Transparency<br>Flexibility                                            |

|                                                                                                 |                                          |                                                                                                                                                                  |
|-------------------------------------------------------------------------------------------------|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                 |                                          | Specialisation<br>Traceability                                                                                                                                   |
|                                                                                                 | Negative impact                          | Higher cost<br>Invalid investment                                                                                                                                |
| Decision-making<br>uncertainties in supply<br>chain management                                  | Environmental<br>uncertainty measurement | The complexity of<br>business environment<br><br>The availability of<br>resources or<br>information in the<br>business environment<br><br>Supply chain structure |
|                                                                                                 | Industry uncertainty<br>measurement      | Bullwhip effect                                                                                                                                                  |
|                                                                                                 | Firm uncertainty<br>measurement          | Technology<br>acceptance                                                                                                                                         |
|                                                                                                 | Impact of IoT                            | Exacerbate<br>Remission                                                                                                                                          |
| Alignment between<br>IoT-based information<br>integration and<br>decision-making<br>uncertainty | Important                                | The goal of supply<br>chain stakeholders                                                                                                                         |
|                                                                                                 | Unimportant                              | The goal of supply<br>chain stakeholders                                                                                                                         |
|                                                                                                 | Impact on supply chain<br>performance    | Positive<br>Negative<br>Unpredictable                                                                                                                            |

## Appendix C Appendices of Chapter 4

### C.1 Survey Instrument

**Table C- 1. Survey Instrument**

Please place a tick (✓) in each question's square box (□) according to your company's and your actual situations. Thanks!

Part 1 Company and personal backgrounds (5 questions)

1. Your company belongs to which node in the supply chain?

|             |                   |              |
|-------------|-------------------|--------------|
| Brand owner | Material supplier | Manufacturer |
| Distributor | Others:           |              |

2. What is your job position in your company?

|                  |                      |                      |
|------------------|----------------------|----------------------|
| Senior Executive | Middle Level Manager | Junior Level Manager |
|------------------|----------------------|----------------------|

Others:

We define the Internet of Things (IoT) as the devices, technologies, hardware, and software that used to support information collecting, selecting, and sharing in supply chains)

3. Has your company implemented/ planned to implement IoT applications?

|     |    |
|-----|----|
| Yes | No |
|-----|----|

4. Do you understand what the IoT applications are, and how the IoT is implemented in the supply chain?

|     |    |
|-----|----|
| Yes | No |
|-----|----|

---

Part 2 Factor of decision-making uncertainty influencing information processing needs (3 questions)

---

We define decision-making uncertainty as: (1) unexpected changes in the business environment. (2) uncertainty occurs during the interaction between supply chain stakeholders, such as demand distortion and unpredictable competition. (3) The uncertainty generated in a firm's operational processes, for instance, the uncertainty in production caused by technology implementation.

1. To what extent does the diversity of component in the business environment increase the requirements of information?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

2. To what extent does the availability of resources or information in the business environment increase the requirements of information?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

3. To what extent does the demand distortion in the supply chain increases the requirements of information?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

---

Part 3 Factor of IoT-based information integration influencing information processing capability (3 questions)

---

We define IoT-based information integration as the information collecting, selecting, and sharing processes along with the infrastructure necessary to do this supported by the implementation of IoT applications

1. To what extent does IoT-based information integration improve information accuracy in the supply chain?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

2. To what extent does IoT-based information integration improve information quality in the supply chain?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

3. To what extent does IoT-based information integration improve information efficiency in the supply chain?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

---

Part 4 The alignment between IoT-based information integration and decision-making uncertainty (9 questions)

---

We define alignment as the degree to which the improvement of the information management process (the methods or technologies used to share information) is consistent with the requirement of information (the decision-making uncertainties) in the supply chain.

1. To what extent does information accuracy impact the demand distortion in the supply chain?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

2. To what extent does information quality impact the demand distortion in the supply chain?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

3. To what extent does information efficiency impact the demand distortion in the supply chain?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

4. To what extent does information accuracy impact the diversity of component in the business environment?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

5. To what extent does information quality impact the diversity of component in the business environment?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

6. To what extent does information efficiency impact the diversity of component in the business environment?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

7. To what extent does information accuracy impact the availability of resources or information in the business environment?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

8. To what extent does information quality impact the availability of resources or information in the business environment?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

9. To what extent does information efficiency impact the availability of resources or information in the business environment?

|          |     |          |        |          |      |           |
|----------|-----|----------|--------|----------|------|-----------|
| 1        | 2   | 3        | 4      | 5        | 6    | 7         |
| Very low | low | Somewhat | Medium | Moderate | High | Very high |

---

Part 5 Impact of the alignment between IoT-based information integration and decision-making uncertainty on supply chain performance (7 questions)

---

1. The alignment between IoT-based information integration and decision-making uncertainty reduces the supply chain's management cost.

|                   |          |                   |         |                |       |                |
|-------------------|----------|-------------------|---------|----------------|-------|----------------|
| 1                 | 2        | 3                 | 4       | 5              | 6     | 7              |
| Strongly disagree | Disagree | Somewhat disagree | Neutral | Somewhat agree | Agree | Strongly agree |

2. The alignment between IoT-based information integration and operational decision-making uncertainty increases the company's working capital.

|                   |          |                   |         |                |       |                |
|-------------------|----------|-------------------|---------|----------------|-------|----------------|
| 1                 | 2        | 3                 | 4       | 5              | 6     | 7              |
| Strongly disagree | Disagree | Somewhat disagree | Neutral | Somewhat agree | Agree | Strongly agree |

3. The alignment between IoT-based information integration and decision-making uncertainty improves the supply chain's asset utilisation.

|                   |          |                   |         |                |       |                |
|-------------------|----------|-------------------|---------|----------------|-------|----------------|
| 1                 | 2        | 3                 | 4       | 5              | 6     | 7              |
| Strongly disagree | Disagree | Somewhat disagree | Neutral | Somewhat agree | Agree | Strongly agree |

4. The alignment between IoT-based information integration and decision-making uncertainty accelerates the supply chain's response speed.

|                   |          |                   |         |                |       |                |
|-------------------|----------|-------------------|---------|----------------|-------|----------------|
| 1                 | 2        | 3                 | 4       | 5              | 6     | 7              |
| Strongly disagree | Disagree | Somewhat disagree | Neutral | Somewhat agree | Agree | Strongly agree |

5. The alignment between IoT-based information integration and decision-making uncertainty improves the supply chain's production flexibility.

|                   |          |                   |         |                |       |                |
|-------------------|----------|-------------------|---------|----------------|-------|----------------|
| 1                 | 2        | 3                 | 4       | 5              | 6     | 7              |
| Strongly disagree | Disagree | Somewhat disagree | Neutral | Somewhat agree | Agree | Strongly agree |

6. The alignment between IoT-based information integration and operational decision-making uncertainty improves the company's product quality.

|                   |          |                   |         |                |       |                |
|-------------------|----------|-------------------|---------|----------------|-------|----------------|
| 1                 | 2        | 3                 | 4       | 5              | 6     | 7              |
| Strongly disagree | Disagree | Somewhat disagree | Neutral | Somewhat agree | Agree | Strongly agree |

7. The alignment between IoT-based information integration and decision-making uncertainty improves the efficiency of the supply chain's operation process.

|                   |          |                   |         |                |       |                |
|-------------------|----------|-------------------|---------|----------------|-------|----------------|
| 1                 | 2        | 3                 | 4       | 5              | 6     | 7              |
| Strongly disagree | Disagree | Somewhat disagree | Neutral | Somewhat agree | Agree | Strongly agree |

**Table C- 2. Survey instrument questions and related literature**

| Questions         | Related literature                                                   |
|-------------------|----------------------------------------------------------------------|
| Part 2 Question 1 | Rajaguru and Matanda (2013); Lee et al. (2016); Pan et al. (2018).   |
| Part 2 Question 2 | James and George (2018); Eker and Eker (2019); Belhadi et al. (2021) |
| Part 2 Question 3 | Zhou and Benton (2007); Lee et al. (2016); Belhadi et al. (2021)     |
| Part 3 Question 1 | Hwang and Rho (2014); Lee et al. (2016); Li and Li (2017)            |
| Part 3 Question 2 | Lee et al. (2016); Ma et al. (2017); Rejeb et al. (2019)             |
| Part 3 Question 3 | Vass et al. (2018); Tao and Qi (2019); Belhadi et al. (2021)         |
| Part 4 Question 1 | Lee et al. (2016); Jain et al. (2017); Gupta et al. (2019)           |
| Part 4 Question 2 | Lee et al. (2016); Jain et al. (2017); Gupta et al. (2019)           |
| Part 4 Question 3 | Lee et al. (2016); Jain et al. (2017); Gupta et al. (2019)           |
| Part 4 Question 4 | Lee et al. (2016); Jain et al. (2017); Gupta et al. (2019)           |
| Part 4 Question 5 | Lee et al. (2016); Jain et al. (2017); Gupta et al. (2019)           |

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|                   |                                                                           |
|-------------------|---------------------------------------------------------------------------|
| Part 4 Question 6 | Lee et al. (2016); Jain et al. (2017); Gupta et al. (2019)                |
| Part 4 Question 7 | Lee et al. (2016); Jain et al. (2017); Gupta et al. (2019)                |
| Part 4 Question 8 | Lee et al. (2016); Jain et al. (2017); Gupta et al. (2019)                |
| Part 4 Question 9 | Lee et al. (2016); Jain et al. (2017); Gupta et al. (2019)                |
| Part 5 Question 1 | Ge et al. (2004); Singh and Garg (2015); Belhadi et al. (2021)            |
| Part 5 Question 2 | Ge et al. (2004); Singh and Garg (2015); Belhadi et al. (2021)            |
| Part 5 Question 3 | Ge et al. (2004); Singh and Garg (2015); Belhadi et al. (2021)            |
| Part 5 Question 4 | Flynn et al. (2010); Durugbo et al. (2014); Fatorachian and Kazemi (2021) |
| Part 5 Question 5 | Flynn et al. (2010); Durugbo et al. (2014); Fatorachian and Kazemi (2021) |
| Part 5 Question 6 | Flynn et al. (2010); Durugbo et al. (2014); Fatorachian and Kazemi (2021) |
| Part 5 Question 7 | Flynn et al. (2010); Durugbo et al. (2014); Fatorachian and Kazemi (2021) |

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