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Information integration and decision-making uncertainty in supply chain management: A relational framework

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Introduction

Mass customisation and service-orientation manufacturing business models have become mainstream in many industries (Azevedo and Carvalho, 2012; Ma *et al.*, 2017). This shortens product lifecycles and leads to smaller volumes and high production diversity, making the products less durable than before (Girneata and Dobrin, 2015; Jain, 2017; Karaosman *et al.*, 2020). Consequently, business environmental dynamism increases (Chen *et al.*, 2014; Moyano-Fuentes and Martínez-Jurado, 2016). Business environmental dynamism reflects the frequency of business environmental changes (Achrol and Stern, 1988), determining the complexity or 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), resulting in a negative impact on supply chain performance. Today, Industry 4.0 brings advanced Information and Communication Technology (ICT) and new management concepts (e.g., smart manufacturing) to supply chain management. Supply chain managers apply these new approaches to improve their decision-making processes (Koh *et al.*, 2019). Firms that adopt Industry 4.0 technologies (IoT, for instance) can improve their information processing capability in the competitive environment (Porter and Heppelmann, 2015; Khajavi *et al.*, 2015). These improvements allow managers to acquire real-time information and communicate with others more quickly, making the whole supply chain network transparent (Odważny *et al.*, 2018; Pérez-López *et al.*, 2019; Seyedghorban *et al.*, 2020).

Extant research has stressed that information integration supports supply chain stakeholders in overcoming decision-making uncertainty and improving supply chain performance (Gao *et al.*, 2005; Plötner *et al.*, 2013; Chen *et al.*, 2014; Valos *et al.*, 2017). 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). Therefore, a holistic perspective is needed to explain how decision-making in supply chain management is affected by information integration and how their interaction influences supply chain performance. In response to this gap, this study conducts a systematic literature review to characterise the relationship between information integration and decision-making uncertainty while considering ICT implementations in supply chain management. We seek to answer the following research question: ***How does ICT implementation impact the relationship between information integration and decision-making uncertainty in supply chain management?***

Research background

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 (Tseng and Lee, 2010; Kuklinski *et al.*, 2012; Sniazhko, 2019). Environmental uncertainty refers to unexpected changes in the business environment (Rajaguru and Matanda, 2013). Industry uncertainty occurs between supply chain stakeholders, such as demand distortion and unpredictable competition (Huo *et al.*, 2014; Ma and Ma, 2017). Finally, firm uncertainty represents uncertainty generated in a firm's operational processes, for instance, the uncertainty in production caused by technology implementation (Li and Lin, 2006). These three aspects are interrelated. For example, during globalisation, a vital element of the business environment uncertainty is taking competition between supply chains from the domestic to the global level (Sahay and Mohan, 2003). The resulting fierce competition accelerates technology development, creating firm uncertainty and causing production delays (Li and Lin, 2006). This delay increases the demand distortion experienced in the supply chain, increasing industry uncertainty (Disney *et al.*, 2004; Adenso-Díaz *et al.*, 2012). When decision-making uncertainty emerges, supply chain stakeholders experience difficulty evaluating the outcome of their decisions to preserve or improve supply chain performance (Raven *et al.*, 1994; Wu *et al.*, 2019).

Information integration. Scholars are constantly updating the definition of information integration. Lee (2000) indicates that information integration is the information sharing process between supply chain stakeholders. Based on this definition, academic opinion is divided. Some scholars propose that information integration is 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 *et al.*, 2013; Büyüközkan and Göçer, 2018). Synthesising these definitions, we define information integration in this research as the processes (or methods) required to collect, select, and share information, along with

the infrastructure necessary to do this.

ICT applications. ICTs are the devices, techniques, and systems that allow users to manage and share information simultaneously (Pérez-López *et al.*, 2019). Implementation of ICTs has been shown to have both positive and negative impacts on information integration in supply chain management. The implementation of one typical ICT application, IoT, provides an opportunity to collect increased volumes of information from supply chain partners, which helps organisations develop new methods to improve customer response and built collaboration (Yang *et al.*, 2013; Parry *et al.*, 2016; Li and Li, 2017). Therefore, it can be concluded that the ability of ICTs to collect real-time information 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). However, high implementation costs and technical issues associated with ICTs set barriers to implementation (Rajaguru and Matanda, 2013). The implementation cost of an ICT solution includes the equipment (hardware and software) cost, training cost, operational cost, maintenance cost, etc. (Remenyi *et al.*, 2007). All these costs need a large amount of investment. For instance, Walmart Canada has invested $3.5 billion in IoT and related technologies in the last five years (Blackman, 2020). Furthermore, the lack of uniform standards causes complexity in connecting ICT to existing information systems in the supply chain (Bottani and Rizzi, 2008). Therefore, although ICT-based information integration is potentially valuable in supply chain management, the risks make the implementation difficult.

An initial theoretical framework is generated (Figure 1), which embeds the research question in information processing theory. The first aspect in the question, information integration implementation, is recognised as an approach that improves information processing capability (Wong *et al.*, 2015; Titah *et al.*, 2016). While the second aspect, decision-making uncertainty, increases the information processing needs in supply chain management (Wong *et al.*, 2011; Shamir and Shin, 2018; Wu *et al.*, 2019). Information processing theory indicates that information processing needs and information processing capability must fit with each other to improve supply chain performance (Öykü Işık; 2010; Cegielski *et al.*, 2012). Thus, to improve their performance, supply chain stakeholders must ensure that the level of information integration fits with the decision-making uncertainty experienced (Fan *et al.*, 2017; Jain *et al.*, 2017; Gupta *et al.*, 2019).

Review methodology

This study explores the research area intersecting supply chain management, information management, and decision-making. Each research area contains a vast amount of literature, and to filter relevant work, we adopted the Systematic Literature Review approach (Tranfield *et al.*, 2003; Durach *et al.*, 2017). The selected keywords and search strings are listed in Table 1.

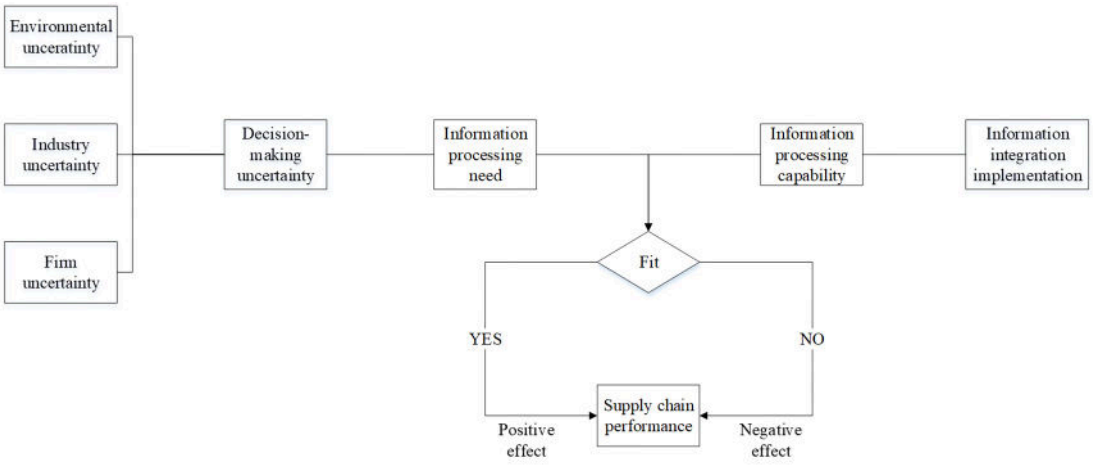

Figure 1. The initial theoretical framework (synthesised from Öykü, 2010; Cegielski *et al.*, 2012; Fan et al., 2017; Jain et al., 2017; Gupta et al., 2019).

Three databases - EBSCO, ABI, and SCOPUS, were selected to ensure comprehensive literature coverage in related research areas. Academic peer-reviewed journals are the main target in the search to ensure the quality of the literature. The search period was limited between January 2000 to June 2022 since there was limited information integration research in supply chain management prior to 2000 (only 5 papers were found with little relevance to the study. After applying the relevance criteria and quality assessment criteria, the final set of articles is 82. The literature analysis was based on a data extraction form and NVivo, a qualitative data analysis software that facilitates the analysis of complex data such as interviews, surveys, papers, etc. (Kuo-Pin and Graham, 2012; Bergeron and Gaboury, 2020). The articles were categorised, and the discussion relating to information integration was distilled using the data extraction form and 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 of Tranfield *et al.* (2003) and Durach *et al.* (2017), the analysis is typically divided into descriptive and thematic.

Keywords	**Search string**
Information and communication technology *Information integration* *Decision making* *Uncertainty* *Supply chain*	"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

Table 1. Keywords and search string

Descriptive analysis

It is observed that there is an increasing interest in the topic of 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 new information technology implementation and related topics have drawn increasing attention following 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 currently hot research directions in the supply chain management field, gaining increased attention from researchers and practitioners (Patnayakuni *et al.*, 2006; Samaranayake and Laosirihongthong, 2016). The 82 journal papers were published in 45 journals. By coincidence, they are CABS-ranked journals (CABS, 2018). As illustrated in the Distribution of papers in journals, most contributions were published in the International Journal of Production Economics (10 papers), International Journal of Physical Distribution and Logistics Management (7 papers), and European Journal of Operational Research (4 papers). The result fits the scope of production and operation-related journals focusing on production, operations, and supply chain management problems. Therefore, unsurprisingly over half of the papers (46/82) appear in production or operations-related journals.

Thematic analysis

A theoretical theme-based classification was created for conducting the thematic analysis to analyse the sample literature and explain the relationship between information integration and decision-making uncertainty, considering the impact of ICT. 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 (Patnayakuni *et al.*, 2006; Pramatari, 2007; Boos *et al.*, 2013). Environmental uncertainty is a critical external driver of information integration in the supply chain, which impacts information integration by enhancing the willingness of supply chain stakeholders to collaborate (Chiang and Feng, 2007; Wong *et al.*, 2011; Attia, 2018). For example, Li and Lin (2006) find that when firms are in an environment with high uncertainty, they are more likely to communicate and cooperate with other supply chain stakeholders. Industry uncertainty is a critical 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.

The impact of information integration is divided into two clusters (positive and negative impacts). Information integration positively influences supply chain management costs, thus improving the relationship between supply chain stakeholders and optimising the

decision-making process by providing accurate real-time information (Stefansson, 2002; Ge *et al.*, 2004; Singh and Garg, 2015). However, the negative impact of information integration should not be neglected. Research has found that difficulties such as high implementation costs make information integration hard to realise (Stefansson, 2002; He *et al.*, 2008; Sivadasan *et al.*, 2013). Furthermore, information integration may increase the risk of revealing a firm's information to its competitors or make it overly reliant on the system, ignoring potential risks (Boos *et al.*, 2013; Chang and Sanchez-Loor, 2020).

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 (Fatorachian and Kazemi, 2021). The implementation of Industry 4.0 ICTs plays a vital role in advancing information technology applications of information integration (Mbhele and Phiri, 2014). 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 (Boos *et al.,* 2013; Szymczak *et al.*, 2018). In addition, evidence in the sample literature indicates that collaboration-based information integration implementation also needs the support of ICTs (Yang *et al.*, 2013; Parry *et al.*, 2016; Li and Li, 2017). For example, it has been shown that one widely adopted collaboration-based implementation tool - CPFR, requires the application of IoT to guarantee adequate real-time information sharing among supply chain stakeholders (Pramatari, 2007; Li and Zhang, 2015). Nevertheless, based on the sample literature, it is still too early to categorise that ICT facilitates collaboration-based integration in the Industry 4.0 era since these studies are theoretical or conceptual (Vijayasarathy, 2010). More empirical evidence is needed to clarify the impact of ICTs on collaboration-based information integration implementation.

Discussion and directions for future research

The sample literature shows that supply chain stakeholders use technology-based and collaboration-based information integration implementation methods to facilitate information management and improve information processing capability. According to the basic framework (Figure 1), an organisation's information processing capability must fit 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 broken down into two aspects: (1) Under high decision-making uncertainty, information integration implementation 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. (2) Under conditions of low decision-making uncertainty, increasing information processing capability by information integration implementation

causes a misfit with the low information processing needs created by low decision-making uncertainty. This misfit hurts 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 needs to 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 the fit between decision-making uncertainty and information integration implementation cannot be achieved, there will be a negative effect on supply chain performance. Based on this analysis of the literature, a modified theoretical framework is proposed by adding environmental and industry uncertainties as essential drivers that enhance supply chain stakeholders' willingness to implement information integration and ICT-based information integration as a method to improve information processing capabilities in supply chain management (Figure 2).

Our research identifies four potential directions for future research,
1. Investigate the influence of other Industry 4.0 advanced technology applications on the relationship between information integration and decision-making uncertainty.
2. Investigate firm uncertainty as an information integration driver.
3. 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.
4. Clarify the benefits and drawbacks of information integration implementation in the supply chain.

Conclusion and contribution

This paper has reviewed the extant literature to analyse the relationship between decision-making uncertainty and information integration while considering the impact of ICT. Following a systematic literature review, the identified literature was classified into broad themes: drivers, impacts, and information integration implementation. This study makes several contributions. From an academic perspective, an initial theoretical framework was proposed using information processing theory as the theoretical lens. A modified theoretical framework was developed by synthesising the literature in the context of the initial framework. This framework demonstrates that the impact of information integration on supply chain performance depends on the information processing needs created by decision-making uncertainty. The modified theoretical framework is used to identify four promising directions for future research.

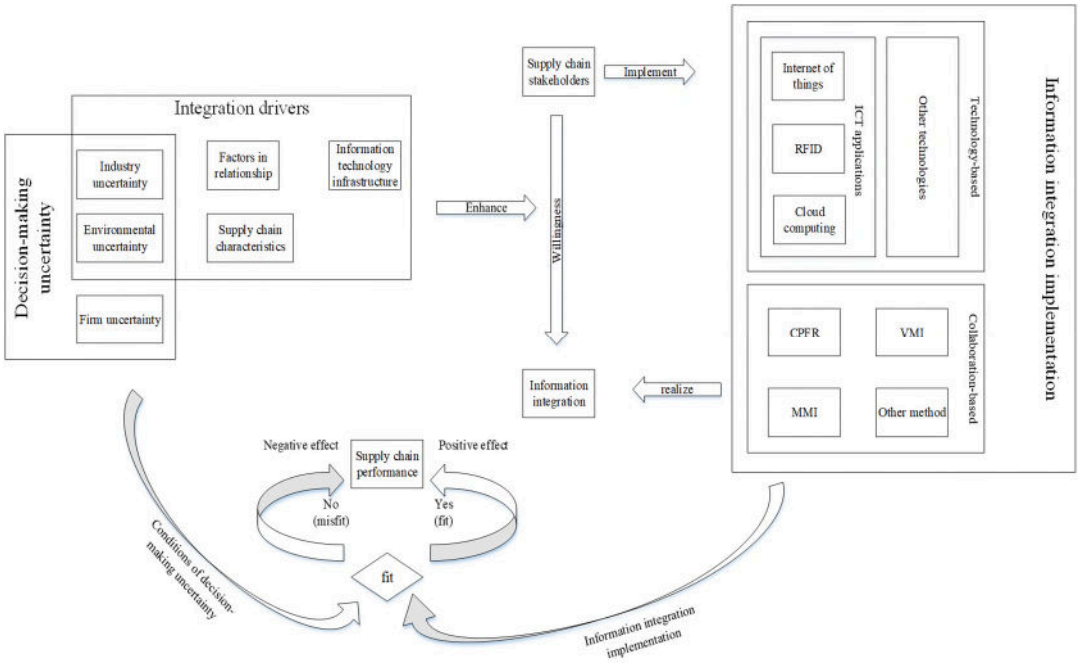

Figure 2. The theoretical relational framework between information integration, decision-making uncertainty, and supply chain performance

In terms of managerial implications, the result of this study can act as a guide for the implementation of information integration. In practice, supply chain managers may be reluctant to adopt new integration implementation 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 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 for their supply chain to improve their supply chain performance. Furthermore, the impact of specific ICT implementation on the relationship between information integration and decision-making uncertainty can act as a tool that aids supply chain managers in deciding which specific technology is most appropriate when seeking a competitive advantage at the supply chain level.

This systematic literature review has a few limitations. Only peer-reviewed journal papers were selected for the review to ensure the papers' quality, which means that some good works may have been missed. Three different databases are used for the review. Thus, papers that are not included in these databases may be omitted.

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Only select references are provided. Full list is available with authors.

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