OPERATIONS AND SUPPLY CHAIN MANAGEMENT
Vol. 14, No. 2, 2021, pp. 148 – 161
ISSN 1979-3561 | EISSN 2759-9363

IoT in Supply Chain Management: Opportunities and Challenges for Businesses in Early Industry 4.0 Context

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ABSTRACT

The Internet of Things (IoT) is a global network of smart devices that integrate physical and digital worlds. While the IoT is reported to be a foundation technology for the emerged Industry 4.0 era, empirical evidence related to IoT use in supply chain management is scant. This study, therefore, investigates the opportunities and challenges of IoT use in the supply chains using grounded theory based interviews with managers from the Australian retail industry. The thematic analysis using NVivo reveals that IoT deployment improves visibility of goods movement, data capture, partner communication, and business intelligence. However, retailers face challenges due to the lack of top management initiative, new technology acquisition cost, stakeholders' reluctance to accept change, unwillingness to share data, and inadequate interoperability between partner systems. The study offers a proof-of-concept of IoT benefits that strengthen the IoT-related investment decision, sheds light on adoption challenges and develops propositions for future research.

Keywords: *Internet of Things, supply chain management, Industry 4.0, grounded theory, retail, IoT, Australia*

1. INTRODUCTION

"The influence of the Internet of Things is crazy," is how a supply chain manager expressed his views that underpin this study. This perception is consistent with the mounting scholarly literature in the area of the Internet of Things (IoT) (Ben-Daya, Hassini & Bahroun 2019; Mishra *et al.* 2016). The IoT is defined as the Internet-enabled global intelligent platform of uniquely addressable devices with sensing, networking and actuation capabilities that facilitates things-to-human, human-to-machine, and machine-to-machine information exchange in heterogeneous environments (Atzori, Iera & Morabito 2010; Birkel & Hartmann 2019; Borgia 2014; de Vass, Shee & Miah 2018). Gartner estimated that 5.8 Billion enterprise and automotive IoT touchpoints would be used in 2020 (Gartner 2019).

Industry 4.0 has envisioned the IoT as a foundation technology of cyber-physical systems due to its increased potency. Its capability to draw on the Internet's power to enable communication and autonomy is fundamental to “smart factory” concept (Ben-Daya *et al.* 2019; Hofmann & Rüsch 2017), which is characterised by autonomous, knowledge- and sensor-based, self-regulating production systems (Hofmann & Rüsch 2017). Alongside, the Internet-disseminated global competition, market volatility and customer demand pose further challenges to firms and their supply chains to mandate new value creation approaches (Balaji & Roy 2017; Manavalan & Jayakrishna 2018). While this paradigm has been argued to happen in the near future, the reality of IoT-led digitalisation and automation in logistics and supply chain context has been in use for a while now (Hofmann & Rüsch 2017; Majeed & Rupasinghe 2017). Given that the SCs compete with each other, a digitally-synchronised one provides better visibility in an extended SC (Ben-Daya *et al.* 2019; Vanpoucke, Vereecke & Muylle 2017).

Digitalisation is the most effective solution for firms facing challenges due to increased flow of goods and lack of information flow for timely decision (Huddiniah & ER 2019). The emerging technologies, such as IoT deployment at the endpoints, are critical for a 'smart' supply chain that helps overcome the current limitations of real-time data capture and sharing (Attaran 2020; Birkel & Hartmann 2019; Sharma & Khanna 2020). Building core ICT infrastructure by integrating the advanced digital capabilities of emerging IoT is necessary due to its potential, affordability and disruptive nature (Ben-Daya *et al.* 2019; de Vass *et al.* 2018; Hofmann & Rüsch 2017). Nevertheless, managers face many challenges for its deployment (Mishra *et al.* 2016).

Literature progressively explores the digital trends in SCM that affect the overall business model (de Vass, Shee & Miah 2020; Sharma & Khanna 2020). For example, the IoT is believed to improve the supply chain integration (SCI) and subsequently enhance SC and firm performance (de Vass *et al.* 2018). However, social and technical challenges hinder the IoT adoption (Haddud *et al.* 2017; Mishra *et al.* 2016). Mishra *et al.* (2016) find limited studies that empirically investigate the IoT adoption in the supply chain. Attaran (2020) agree that studies in this area are primarily theoretical. Mishra *et al.* (2016, p. 1347), therefore, urge scholars to study *"... the drivers and barriers of IoT implementation and adoption in SCM"*. An exception to this was a study by Haddud *et al.* (2017) who investigated the opportunities and challenges of IoT where the survey respondents were the academics, not the IoT users in the field. While, Kenney *et al.* (2019) argue that digitalisation can create economic value through innovation, the paucity of empirical evidence poses a barrier for firms to make informed decisions on IoT investment (Attaran 2020; Birkel & Hartmann 2019; Haddud *et al.* 2017). Meanwhile, COVID-19 has created a new norm that necessitates intensive ICT use to manage the global supply chains. The pandemic has forced the firms to embrace the appropriate technologies for remote operations (Baldwin & Tomiura 2020).

This study, therefore, aims to explore the opportunities and challenges of IoT adoption and use in SCM for performance improvement. The Australian retail industry is seen to be at the forefront of IoT and other technologies deployment because the retailers attempt to bring the digital shopping experience to in-store customers while making their digital presence. This digital disruption has allowed the customers to choose when, where and how they acquire their goods and services (Deloitte 2020). The retailers have the readiness to face the novel technological challenges in meeting consumer demands (Balaji & Roy 2017; Caro & Sadr 2019; Majeed & Rupasinghe 2017). The widespread integration of digital platforms is redefining the scope of retail competition (Kenney *et al.* 2019), as evidenced by omnichannel retailing strategies for a smart way of dealing with inventories and related operations with customers touchpoints (Caro & Sadr 2019).

The remaining part of the paper is organised as below. Section 2 of this paper reviews the literature on the IoT in SCM and its opportunities and challenges; Section 3 outlines the research methodology; Section 4 presents the findings and discussion of the study along with research propositions; Section 5 undertakes the discusses and implications and Section 6 offers concluding remarks.

2. LITERATURE REVIEW

2.1 *The Internet of Things*

The IoT is not a single technology, but an innovative alliance of several complementary technologies united to bridge the gap between the digital and the physical world (Balaji & Roy 2017; de Vass *et al.* 2018). The term 'Internet of Things' was first coined in 1999 by the members of the Massachusetts Institute of Technology's (MIT) Auto-ID Center for SCM for a process to track items via the Internet with the use of radio-frequency identification (RFID) linking to an Electronic Product Code (EPC) serving as a universal identifier for each specific item (Birkel & Hartmann 2019; Tu 2018). Since then, the notion of 'Thing' has broadened to include many digital devices (e.g., RFID, sensors, actuators, smartphones, smart items) that can be uniquely identified, read, sensed, located, addressed and controlled autonomously via the Internet (Mishra *et al.* 2016; Tu 2018). The capabilities of IoT devices are posited to exceed the innate functionalities of any device by using the Internet as a communication infrastructure, storage mechanism, and medium for data processing and synthesis (Atzori *et al.* 2010; Borgia 2014). Nowadays, the IoT platform is further augmented through GPS telematics, social networks, cloud computing, and (big) data analytics (Atzori *et al.* 2010). Key characteristics of the IoT include self-awareness, individuality, control, interconnectivity, flexibility, transformability, synergy, self-decisiveness, and strategic behaviour (Balaji & Roy 2017; Evtodieva *et al.* 2020). Scholars have predicted that the IoT can generate social, economic, and environmental benefits through these features and capabilities (Atzori *et al.* 2010; Manavalan & Jayakrishna 2018).

2.2 *Industry 4.0 and IoT*

The IoT is reported to be an enabler of the emerging Industry 4.0 era of automation and digitalisation (Balaji & Roy 2017; Ben-Daya *et al.* 2019; Hofmann & Rüsch 2017). While the three earlier industrial revolutions relate to mechanical power (Industry 1.0), mass production (Industry 2.0) and the digital revolution (Industry 3.0), Industry 4.0 unveils smart products, smart machines and intelligent services such as quality-controlled production, logistics and maintenance (Ben-Daya *et al.* 2019). Since Germany launched the Industry 4.0 initiative in 2011, then being listed as a core topic on the 2016 World Economic Forum's agenda, the aura of IoT as one of the most influential technologies has come to the limelight (Ben-Daya *et al.* 2019; Hofmann & Rüsch 2017). While Industry 4.0 meant to transform the industrial production to next level, its pure vision can only become a reality if the SCs can run cohesively by becoming more digital, self-assisted and information-led (Hofmann & Rüsch 2017; Manavalan & Jayakrishna 2018). Therefore, the integration of logistics processes with Internet-connected technology is crucial for Industry 4.0 (Ben-Daya *et al.* 2019). Further, the IoT platform helps integrate the supply chains processes with external partners like suppliers and customers for significant performance benefits (de Vass *et al.* 2018). In the early Industry 4.0 context, while IoT applications can assist in real-time asset tracking, tracking of material flows, improved transport handling, and accurate risk management, the envisaged potential is a self-sustained supply chain platform through complete automation with minimal or no human intervention (Manavalan & Jayakrishna 2018).

SCM's transition to Industry 4.0 is constrained by reliance on discrete data silos, meaning the data is often not immediately available (Ben-Daya *et al.* 2019; Kaya 2020). The IoT, conversely, has the potential to transform the SC into an integrated system and facilitate the transition to Industry 4.0 by bridging information gaps via real-time tracking of product flows, information exchange and automated handling (Birkel & Hartmann 2019; Hofmann & Rüsch 2017; Manavalan and Jayakrishna 2018).

2.3 IoT and Supply Chain Management

The IoT in the industry is not limited to large, resourceful firms and their SCs. It is broadly available technology and widely used to perform diverse roles in SCM (de Vass *et al.* 2018; Kaya 2020) including linking information with vendors; gathering real-time progress data from vendors; providing visibility on parts and raw materials; generating real-time quality/maintenance data; inventory tracking, information sharing, and joint ordering; quality monitoring and quality-controlled logistic; enabling enhanced reverse logistics; and capturing product data while in use to generate operational efficiencies and maximise revenue opportunities (Ben-Daya *et al.* 2019; Kaya 2020). Sensor technologies are also becoming increasingly ubiquitous in vehicles, enabling real-time interaction between the vehicle and its environment and contributing to faster speeds and vehicle platooning to reduce journey times, congestion and increase existing infrastructure capacity (Hopkins & Hawking 2018). Availability and analysis of IoT-enabled real-time data ultimately allow stakeholders to make better operational decisions and enhance strategic outcomes at both SC and firm-level (Balaji & Roy 2017; Büyüközkan & Göçer 2018). Hopkins and Hawking (2018), for example, document the role of IoT and big data analytics in a logistics firm to improve driver safety, operational efficiency, and environment.

Despite the promise of the IoT, there are numerous challenges to its adoption and use (Haddud *et al.* 2017; Whitmore, Agarwal & Da Xu 2014). Tu (2018) finds that many firms hesitate to invest in the IoT because they are not fully aware of their capacities. The difficulty of predicting how digitalisation may affect industries is partly due to its remarkably pervasive impacts, particularly as technologies become insidious, pervasive, and ubiquitous (Attaran 2020; Kenney *et al.* 2019). While the cost of IoT hardware such as RFID tags and readers has declined, many are still cautious about IoT-related investments (Tu 2018) due to social, financial, and technical factors (Ben-Daya *et al.* 2019). Among the main barriers to adoption is the integration of logistics processes along the supply chains with heterogeneous technologies and data services (Haddud *et al.* 2017), with security, ethical, privacy and standardisation considerations, among other vital barriers (Borgia 2014). Also, extra attention to reducing e-waste is necessary for environmental sustainability (Alieva & Haartman 2020). Alieva and Haartman (2020) suggest considering e-waste created by Industry 4.0 automation as a new type of e-waste to focus on its reduction and to generate new revenues via reversed logistics. Whitmore *et al.* (2014), in their literature review, classify barriers into security, privacy, legal/accountability, and general; these prevent managers from benefiting from the IoT's potential for visibility (Haddud *et al.* 2017). While information sharing has always been a challenge in SC context, interoperability can unlock the real value of the IoT (Ben-Daya *et al.* 2019). Sharing the captured data in a single IoT platform can provide mutual benefits to all SC partners (de Vass *et al.* 2018). Because of divergent scholarly views regarding the opportunities and challenges posed by the IoT in SCM and the recent proliferation of its practical application and research, this topic requires first-hand narratives from practitioners who are directly involved its use (Birkel & Hartmann 2019; Evtodieva *et al.* 2020).

It is crucial to pragmatically understand how those emerging smart devices connect all channel partners anywhere, anytime, improve visibility in the supply chain and benefit channel partners (Sharma & Khanna 2020). However, there is limited empirical research that has investigated its potentials in SCM context, with current scholarship discussing the application of the IoT to SCM rarely integrating management and operations perspectives (Ben-Daya *et al.* 2019; Evtodieva *et al.* 2020; Haddud *et al.* 2017; Kaya 2020; Mishra *et al.* 2016). In a recent study, Kaya (2020) attempts to conceptualise the IoT in SCM, while others (e.g., Attaran 2020; Birkel & Hartmann 2019; Evtodieva *et al.* 2020) endorse proof-of-concept through literature reviews. Caro and Sadr (2019) classify IoT initiatives on an opportunity map that distinguishes the initiatives by their value in decoupling supply and demand in retail; in so doing, they highlight that its true potential resides in unexpected benefits following IoT adoption. However, in-depth empirical narratives of IoT adoption and use are required to comprehend such benefits better. Due to lack of proof-of-concept, many firms still hesitate to fully consider the importance of aligning emerging ICT within the supply chain and business conditions (Huddiniah & ER 2019). Limited empirical evidence in the field has been provided by Haddud *et al.* (2017), who survey academics but recommend essential avenues for future research using open-ended questions with industry practitioners to gain practical insights, while the literature review by Mishra *et al.* (2016) concludes by asserting the need to conduct case studies with grounded theory approach to explaining the intricacy of IoT integration in SCM.

3. METHODOLOGY

This study investigates IoT applications in retail supply chains through interviews approach with a sample drawn from the Australian retail industry. It thus generates new empirical evidence and insights to validate, extend, and complement the IoT proof-of-concept. The interviews deem appropriate because: a) the exploratory design reveals the phenomenon at an early stage of maturity (Ardolino *et al.* 2017; Mishra *et al.* 2016), and; b) the qualitative methods are effective in understanding managers' perspectives on the phenomena (Mello & Flint 2009) and yield insight into the complex phenomena by investigating the interaction between individuals and technologies in a complex supply chain (Randall, Flint & Mello 2012).

3.1 Research Approach

A grounded theory (GT) approach is suitable in such emerging and complex research situations because it allows researchers an open mind (Charmaz & Belgrave 2007; Mishra *et al.* 2016). Prior research on IoT in SCM context has relied on GT to initiate the research process with an open mind (Tu 2018). The GT centres on the systematic gathering and analysis of data to derive theory, understand a new phenomenon and develop future research propositions (Kaufmann & Denk 2011; Mello & Flint 2009; Randall *et al.* 2012; Strauss & Corbin 1997; Tu 2018). Importantly, the GT allows researchers to hold an open mind to uncover new concepts inspired by emerging patterns (Charmaz &

Belgrave 2007; Glaser & Strauss 1967). This approach helps researchers understand the human side of SCM, the underlying meaning of human experiences, interactions, and relationships that constitute company strategies and follow up actions (Randall *et al.* 2012). Likewise, interviews conducted within GT studies are conducted and analysed with considerable attention to emerging patterns than is the case with other qualitative methods (Mello & Flint 2009).

3.2 Participant Selection

The present study examines the narratives of senior managers involved in SCM in the Australian retail industry. Expert interviews are useful when exploring a new but under-investigated phenomenon (Littig & Pöchhacker 2014), such as IoT use in the retail sector. Participants and their organisations were recruited through social media contacts (e.g., Facebook and LinkedIn), and written consent for participation was secured. Non-random sampling helps gain a better understanding of a phenomenon that is still emerging (Tu 2018). Sampling sought a broad representation of retail sectors, firm sizes, retail forms (e.g., brick-and-mortar, e-tail or omnichannel), and maturity of IoT deployment. To participate, individuals had to have hands-on experience in the implementation of IoT. This was an important variable to ensure adequate depth and breadth of insights. In total, 13 interviews were undertaken. One senior manager for each of 12 retail firms was interviewed. Also, the participants strongly emphasised 3PL (third-party logistics) service providers at the forefront of IoT adoption and recommended seeking their advice on the IoT. Therefore, a manager from a 3PL service provider (i.e. 3PL-X) was also interviewed. The 3PL-X is one of Australia's largest and provides 3PL services to most of the retailers in the sample. However, as 3PL is an outlier to the unit of analysis of this study, his narrative was used for clarification purposes only. Deviation from the original unit of analysis in the direction of a different unit of analysis is encouraged in GT literature (Charmaz & Belgrave 2007; Glaser & Strauss 1967).

3.3 Sample Size

The sample size in qualitative research in general, and GT in particular, is extensively discussed in the literature (Guest *et al.* 2016). In terms of sampling in interview approach, Hennink *et al.* (2017) suggest that "a sample size of nine is sufficient for code saturation, but would only be sufficient to develop a comprehensive understanding of explicit issues in data and would miss the more subtle conceptual issues and conceptual dimensions which require much more data". While noting that twelve interviews may appear insufficient to attain generalisation (Guest *et al.* 2016), the study applied GT approach not particularly to generalise the findings, rather understand opportunities and challenges for IoT in SCM via practical experiences of retailers (Kaufmann & Denk 2011). Rather than generalising per se, this exploratory paper aims to capture every day "complexity, nuance and dynamic" (Emmel 2013) of IoT in supply chain management. The twelve interviews are sufficient for code saturation, develop a comprehensive understanding of specific issues in data, explore opportunities and challenges of IoT deployment in retail supply chains, but may miss the more subtle conceptual issues and conceptual dimensions which require more data (Hennink *et al.* 2017). The 12 interviews were, therefore, deemed adequate for fulfilling the study objective of gaining empirical insight into the opportunities and challenges of IoT deployment in retail SCs.

3.4 Data Collection Method

Like most other GT studies, this study relies on loosely-structured individual interviews (Mello & Flint 2009). Individual interviews provide rich data by allowing the interviewer to grasp background information and engage in unstructured communication. Open-ended interview questions were designed to explore IoT adoption and use in their SCs from retail firm perspectives and encourage participants to discuss new ideas and facts without constraints (Haddud *et al.* 2017). In this study, this approach allowed for the identification of key themes while providing the flexibility for researchers to flesh out the empirical manifestations of these themes within participants' retail firms in free-flowing conversation.

The interview schedule comprised eight questions under two sections: Section 1 sought to a) characterise the Retailer and its SC, the participant, and her or his understanding of IoT, and; b) produce a list of IoT technologies deployed within the firm via a verbal questionnaire. Section 2 explored opportunities and challenges of IoT adoption in SCM using open-ended questions. Question-wording was examined by the researchers to minimise preconceptions, such as social desirability bias. Critical insight was also sought from three SCM academics, followed by the conduct of three pilot interviews with retailers aimed at ensuring the clarity and relevance of questions, and content validity. Interviews lasted between 45 minutes and 1 hour. As per a GT approach, data collection and analysis were conducted both during and after the interview process. The loose structure of interviews allowed ample opportunity to discuss emerging themes and identify a broad range of conceptual categories (Charmaz & Belgrave 2007). Salient themes and categories arising from discussions were progressively added to interview schedules (Kaufmann & Denk 2011).

3.5 Data Analysis

Interviews were transcribed, then coded using the open-coding process typically used in GT qualitative research (Glaser & Strauss 1967; Randall *et al.* 2012; Strauss & Corbin 1997). As per GT theoretical framework, content analysis method was used for textual data analysis. In line with GT studies, analytic categories, or themes were directly derived from the data, rather than preconceived concepts or hypotheses (Charmaz & Belgrave 2007). NVivo 11, a widely used computer-assisted qualitative data analysis software suite, was used to conduct line-by-line coding and categorise, organise, consolidate, and identify relationships between coded themes and sub-themes. This process involved categorising segments of transcripts according to themes (Tu 2018). The researchers also sought to identify patterns and relationships across the data, a process known as axial coding; concept nodes were formed and classified into themes to understand what relationships the qualitative data represents. The coding process was repeated twice to refine the analysis further.

Further, an independent researcher was engaged to carry out the coding process, with the results cross-checked to validate and/or refine the initial analysis (Ardolino *et al.* 2017). Themes emerged are presented as findings.

4. FINDINGS

4.1 Overview

The sample, representing 12 retail sectors, covers all retail industry classifications stated in the Australian Bureau of Statistics (ABS). The majority were large firms (7, >200 employees) while the rest (5) were medium-sized (20< & <200). Respondent firms fall into bricks-and-mortar, e-tailing, and omnichannel retail forms. **Table 1** presents the profile of participants/retailers, with individual identities decoded for anonymity.

4.2 Perception and Progression of the IoT

Participants' definitions of the IoT were congruent with scholarly definitions. For example, Retailer I described it as *"an umbrella term used universally for the mechanics behind it, devices capitalising the power of the Internet"*; *"IoT for me is things that are connected anywhere, anytime, that you can access when you want, where you want"* [3PL-X]. Retailer K explained the benefits of the IoT as reallocating *"...analytics from the edge (the device itself) to the Cloud. It can communicate instantaneously, update all devices remotely, get the information from anywhere in real-time"*.

Table 1 Summary profile of subject retailers

ID	Code	Work exp.	Job role	Retail sector	Key retail form	Firm size	First adapted IoT
1	A	2 yrs.	Supply chain manager	Cosmetic and toiletry	Omni-channel	Medium	Less than 2 years ago
2	B	11 yrs.	Supply chain manager	Department store	Bricks-and-mortar	Large	Over 11 years
3	C	3 yrs.	Supply chain manager	Supermarket	Bricks-and-mortar	Large	4 years ago
4	D	2 yrs.	Supply chain manager	Pet products	Omni-channel	Large	5 years at-least
5	E	3 yrs.	Owner	Restaurant/café/take-away	Omni-channel	Medium	3 years ago
6	F	4 yrs.	Supply chain manager	Telecommunication products / Electronics	Omni-channel	Large	3 years ago at least
7	G	5 yrs.	Supply chain manager	Clothing, footwear and personal accessories	Omni-channel	Large	Over 15 years
8	H	10 yrs.	IT manager	Motor vehicles parts and Electronics	Omni-channel	Medium	5 years at-least
9	I	5 yrs.	Supply chain manager	Supermarket	Bricks-and-mortar	Large	10 years at-least
10	J	20 yrs.	Store manager	Fuel and convenience stores	Bricks-and-mortar	Large	5 years ago
11	K	5 yrs.	IT manager	Security and surveillance/ Electronics	Omni-channel	Medium	5 years ago
12	L	7 yrs.	General manager	Household goods	E-tail	Medium	6 years ago

*3PL-X is not part of this table because it was not considered as the fundamental unit of analysis

Participants also discussed the IoT as a clever unification of several fundamental technologies growing in many innovative forms, rather than a single specific technology. This finding is in line with the conceptualisation dominant in the literature (e.g., Atzori *et al.* 2010; Borgia 2014), As Retailer K asserted, *"...the world nowadays even though people don't realise it is an 'Internet of Things'. Knowingly or unknowingly, there are at least 1 or 2 'Internet touchpoints' from a person to the outside world"*. The collective opinion was that IoT had emerged strongly in recent times as an industrial application, and all participants optimistic about its potential in SCM. *"I believe IoT has an epic potential in SC operations"* [Retailer C]. Participants also unanimously asserted that they would like to explore its potential: *"Such technology that makes our SC smarter and faster, we would look at it in positive eyes"* [Retailer B].

Eight retailers highlighted RFID as an early form of IoT: *"I recall talking about RFID technology 20 years ago…. I don't think it's still mainstream"* [Retailer I]. However, item level identification via RFID had not been implemented among any subject SCs. Retailer J reported testing the scenario, but only Retailer G had immediate plans: *"We are looking at implementing RFID as one of our products costs minimum 20 to 30 bucks, and a tag will cost only 5 to 10 cents"*.

RFID in specific did not capture the same optimism as IoT in general, primarily due to cost constraints: *"RFID tagging and tracking of low-cost FMCG products still seem quite expensive"* [Retailer I]. However, six participants argued that RFID would nevertheless be advantageous: *"RFID will be very handy, particularly around dating the products within our store"* [Retailer D]. Both open and closed standard barcoding remained the preferred and most economical short-term strategy for product identification, whereas Retailers G, H and I tested image recognition as an alternative.

While all participants framed the IoT a part of broader ICT infrastructure, they all distinguished it because of its familiarity: *"As a technology, IoT is getting into the Australian market these days. As we see, the market is mature enough to understand about IoT"* [Retailer K]. Six retailers framed the IoT as addressing the inadequacies inherent in traditional ICT in facilitating business needs: *"The email and phone conversations to raise orders is not so adequate for planning and transparency"* [Retailer A]. This finding is consistent with those of a survey conducted by de Vass *et al.* (2018). As per the findings on the progression of IoT, a proposition is developed:

Proposition P1*: Although it cultivates the core concept of drawing on the Internet's potency for additional capability, the evolution of various forms of IoT in supply chains is not linear.*

4.3 Status and Uptake of IoT in Retail SCM

IoT technologies convert physical parameters like temperature, shape, humidity, and speed into a digital signal (De Vass *et al.* 2018). Five retailers use RFID on a unit level, such as box, pallet, and container. Other forms like barcode, PDAs (personal digital assistants), RF (radio frequency) scanners, laser and LED scanners, and camera-based scanners were widespread in warehousing and retail stores. Voice pick, automatic guided vehicles (AGV), and automated pallet movers or conveyor control systems were also used in warehouses. Point-of-sale (POS) devices, sensors, video analytics (facial recognition for customer recognition, advertising via machine learning and context-aware offers), IP (Internet Protocol) cameras, barcoding (unique for some perishable items), mobile scanning/purchasing, mobile payments, and payWave were widespread. Smartphone applications in food retail help customers choose restaurants/products, order, pay, and track the delivery.

Rather than having many IoT devices for different purposes, there was a drive for consolidation: *"The trend now is using the same device for multiple purposes"* [Retailer H]. Exploiting the built-in capabilities of smartphones was a theme discussed by five managers. Given the contemporary near ubiquity of smartphones, there seems to be an effort to piggyback on their resources as the central integration device. Retailer H explained their push to substitute the functionality of handheld devices to smartphones in their Distribution Center (DC). Retailer G stated that chips (sensors) in the shoe's sole are no longer necessary due to smartphones having enough sensors to measure *"running, vibration and everything else"*. 3PL-X reported two methods of consolidation: one is using fewer devices by re-assigning functions to smartphones; the second is moving from each in-cabin device (e.g. tablet, GPS, camera) having a SIM card within towards the use of a single SIM card connecting all devices through the smartphone. Retailer H highlighted the environmental perspective of consolidation of tasks into a single device rather than using multiple devices: *"Using existing devices rather than adding new devices is good for the environment as well"*.

All participants indicated that the IoT has been in place in their SC for at least the past two years: *"IoT has been in SCs for many years in various forms"* [Retailer K], and that their firms adopted the IoT to a reasonable degree as a mix of 'things' across different SC processes at different intensities. However, Retailers G, E, and H felt they were ahead of their competitors, while Retailer A, F, and L thought they were behind. As the market leader, Retailer G highlighted the importance of IoT investment to stay ahead in competition: *"If you don't stay with evolving technology, you are going to lag behind"*. Retailer L conceded their technology capability as a limitation in competing with large retailers: *"I think some of our constraints in the business while competing with large retailers are around technology side; they are so much ahead in terms of IoT at the moment"*. This finding is consistent with the diffusion of innovations (DOI) theory, which suggests that 'relative advantage' is one of the five characteristics of innovation that affect technology adoption (Rogers 2010).

The progressive adoption curve of innovators stipulated by DOI theory includes a minority of innovators followed by early adopters, early majority, late majority, and laggards (Rogers 2010). Retailers B, G, E and I were early adopters of IoT technology, while other retailers cautiously observed others before investing: *"We are watchful about what's happening at the marketplace, we are looking for the ways to do things, but not necessarily jump in straight on them"* [Retailer C]. Retailers A, F, and L felt they were lagging due to multiple reasons such as cost, knowledge, and their business model. Therefore, we propose a proposition as below:

Proposition P2*: While various forms of IoT are advancing with multiple functionalities, the drive for consolidation of these devices positively influences the likelihood of its adoption in SCs.*

4.4 3PLs Role in IoT Proliferation in Retail Supply Chains

Aside from early adopters, most retailers got their first IoT experience through 3PL services. For example, the 3PL-X participant has been using the IoT since 2005 in their haulage systems and since the mid-90s in DCs. All participant retailers outsource a more significant component of their logistics functions to specialised 3PL service providers; most transport functions are outsourced by all, while 8 have their distribution centres (DCs) run by 3PLs. Retailers K, E, and F use fourth-party logistics (4PL) integrators, which assemble and manage service providers. According to 7 participants, technological aptitude was a crucial criterion in 3PL service provider selection: *"When we look at 3PLs, we always look at transporters who have the best technology, so that they can provide the best for us and the best for our customers"* [Retailer L]. For example, 3PL-X's firm uses many IoT technologies in its haulage operation, such as GPS telematics with driver identification for vehicle tracking; produce a track and trace history; speeding information; route optimisation; fleet controlling; route consideration; duress alarms; man down pendants video cameras; smartphone apps; sensors to remotely monitor the temperature in cold chain logistics; IoT retina scanners and facial recognition cameras to monitor driver fatigue, and; fleet management systems to monitor idle time and preventive engine maintenance. Drivers also use *"sign on glass"* instead of paper and various handheld devices.

All participant firms have IoT-enabled 3PL service providers integrated into their processes, facilitating tracking of inbound movement, or offering customers ways to track their deliveries. Retailers A, E, K, and L highlighted the saving resulting from investment in such technology. 3PL-X corroborated this finding, stating that they probably had won many contracts because of their technological capability, while they have lost others because they didn't have the right technology. Participants further indicated that not having long-term contracts hinders technology deployment in the 3PL space because of return-on-investment concerns. As 3PL-X stated, *"...aside from safety, the end goal is, you keep the contract"*, but also complained that, *"they (retailers) go all the way to ensure we have it, then we provide it, but they never use it!"* Therefore, a proposition is proposed as,

Proposition P3*: The 3PL service providers play a significant part in driving the intensification of emerging technology in SCs.*

4.5 Data Capture, Analysis, and Sharing

Whitmore *et al.* (2014) argue that current scholarship needs to answer the question: 'how does the IoT fit into the big data movement?' In a response engaging with this question, 3PL-X explained that *"having this technology is purely information gathering. Your data always limit the depth and the effectiveness of analysis"*. Ten retailers talked about the benefits of analysing data captured by the IoT: *"When I think about IoT, it is data, it's capturing tons of data"* [Retailer G]. Seven retailers made a direct comparison of IoT data capture, particularly compared to traditional ICT: *"Capturing of the data that we didn't have access to before is a massive opportunity we have with IoT"* [Retailer H]. Those who had captured the data earlier did not see its value in business intelligence. Now, data-driven decision-making is at the forefront.

The data analysis impacts many areas of operation, including forecasting and planning; understanding customer needs; operational, tactical and strategic business decisions; evaluation of staff, instruments and processes auto-reporting and ordering, and; process improvement: *"Through data analysis, we have found gaps in our delivery operations"* [Retailer A]; *"We have been able to get more information, more visibility of information and make better decisions based on information, which has helped our flow of stocks and helped reduced our stock level"* [Retailer B]. Retailer G summarised the IoT effect on analysis as follows: *"In the end, if we can get the right data and effectively communicate that converts into better service levels for the customers"*.

While acknowledging the benefits, three managers cautioned on the volume and complexity of IoT data: "Of course, there is a better performance outcome via analysis of IoT data. But at first, it can be quite confusing, so you must get it clear in your mind on what you need to look at [Retailer B]; *"If you are good at it and know how to use it, it's a really a game-changer. It can also clutter your life"* [Retailer D]. Seven retailers identified reporting as a critical improvement made by the IoT, with five particularly highlighting the advantages of real-time analytics and reporting. Real-time streaming analytics is a significant feature of prevailing IoT systems (de Vass *et al.* 2018), a finding corroborated by participants: *"Streamlining of reports is immediate. Managers can see these statistics live and make decisions. But if you don't have these IoT devices integrated, it will take weeks or months. By the time you realise the issues, it's too late"* [Retailer H]. Similarly, Retailer I stated that *"real-time reporting and inventory management is the primary driver for us to implement IoT"*.

Six retailers discussed in-house cross-functional sharing of data and findings: *"IoT data is pretty much shared with all functional teams"* [Retailer A]. Retailer D explained their real-time analytical tool displaying key information to all managers via a smartphone app, while seven retailers had their transporters sharing analysis findings with them: *"They (transporters) always provide us with reports on outcomes, their success rate and such"* [Retailer L].

While no firm shared raw captured data with SC partners, ten retailers indicated that they analyse data in-house and share findings with SC partners: *"We don't share data with our supply chain partners, we just share the outcome. We don't want to expose our data. But sharing results have helped us improve our processes"* [Retailer H]. Six retailers highlighted sharing findings with suppliers: *"The supplier is waiting for that visibility in the planning process. We provide visibility to the supplier two years in advance"* [Retailer G]. However, only Retailers E and F had suppliers sharing findings with them.

As the IoT is found as the catalyst for Big Data analytics, the following proposition is proposed as:

Proposition P4*: The IoT adoption enables Big Data analytics, therefore positively related to additional data collection, analysis, and business intelligence development.*

4.6 Drivers for IoT in Retail SCM

The retail industry was generally discussed as *"very competitive,"* and the IoT was viewed as a technology to help enhance competitiveness and sustainability: *"You have to have an excellent SC because there is so much competition. That's where IoT comes in to play"* [Retailer L]. Apart from this typical external driver for IoT adoption in retail SCM, eight retailers accentuated improved Internet transmission speed, while the same number highlighted better affordability as crucial drivers: *"The Internet is better, and the prices are continuously going down"* Retailer E].

Eight participants argued that the proliferation of the IoT as a personal application had stimulated its industry application: *"Every person has devices meant to be IoT devices now, so they expect to use them at work too"* [Retailer J]. Despite being a personal device, all participants framed smartphones as a tool for operator and customer integration into SCs. Smartphones also seem to play a vital role in industry IoT context as an H2M integrator: *"Now a day everyone carries a smartphone, a form of IoT device which is always connected to the Internet"* [Retailer K]. Retailer D explained their smartphone app notifying operational data for staff. Many had apps for customers. Retailer E reported that smartphone apps had revolutionised the restaurant industry, connecting them with customers and deliverers. In particular, six retailers asserted that the younger generation at work and customers had accelerated the use of smart devices: *"Most of them are young people, so they love these kinds of apps. I'm talking about customers and staff, both"* Retailer E].

4.7 Nature of Business and IoT Adoption Decisions

Firm-specific characteristics also affected IoT adaption decisions. This was a theme raised by nine retailers. Retailer C, being a multinational business, asserted that a state-of-the-art roll out was awaited. Retailer G thought that as a global enterprise and market leader, they were at the forefront of innovation. Retailer I, from the fast-moving consumer goods (FMCG) sector, mooted the nature of their products as a decisive factor: *"Relative to the cost of the consumer products, some of these IoT ideas are still considered quite expensive"*. Retailer L believed that their products arriving into the warehouse in components were the key deterrent. Highlighting customers' expectations of the restaurant sector as the key factor, Retailer E stated that, *"digital devices and smartphone apps are almost a necessity and a standard"*. While Retailer A, D, and L cited the infancy of their firm negatively affecting IoT adoption, Retailer L further added firm size: *"We are a small business lacking experience"*. Retailer D's declining market shaped its decision on IoT deployment since *"they don't want to invest in a shrinking market"*.

4.8 Enablers of IoT Deployment in SCM

The key motive for IoT adoption discussed by 9 retailers was its efficiency: *"Because it enables efficiency in terms of movement of goods in the SC"* [Retailer A]. In terms of efficiency, 6 participants each cited time saving and reduced manual work; 5 each cited productivity and speed; 4 cited process optimisations, and 3 noted cost minimisation. Six retailers revealed visibility as a motive: *"To get access to information and the visibility of information"* [Retailer D]. All participants cited real-time data capture. As Retailer L said, *"having access to information in real-time capacity"*. Three retailers discussed acquiring more (in-depth) data for better decision-making: *"Having the right devices to record the data and use that data to provide a better service is the biggest motive"* [Retailer G]. Three mentioned accuracy: *"Accuracy of data is obviously better when a device is doing it for you"* [Retailer H]. Three respondents cited security and surveillance, remote access, customer satisfaction, and the industry-standard: *"We wanted the capability of telling that device in real-time"* [Retailer K]; *"We are forced into these things because of the retail requirement"* [Retailer A]. Other motives cited include building consumer trust, improving sales, and improving SC communication. Retailer E stated that *"to stay in touch with both suppliers and customers"*, while 3PL-X stressed the importance of having historical IoT data available for retailers in contingencies. As the IoT is found as the catalyst for Big Data analytics, the following is proposed.

Proposition P5*: The IoT's enabling capacities (i.e., efficiency, visibility, and accuracy) have a positive influence on its investment decision.*

4.9 Benefits of IoT in SCM

3PL-X asserted that *"we all know that the benefits are there, you don't actually have to sell IoT technology"*. Ten retailers cited the benefit of better visibility than traditional ICT: *"SC is all about connecting the dots. IoT gives us visibility"* [Retailer A]. Similarly, six retailers emphasised real-time visibility: *"IoT is streamlining it (DC) live right now"* [Retailer H]. Higher intelligence via in-depth IoT data was cited by ten retailers, while 5 highlighted real-time streaming analytics for immediate action/reaction. Seven retailers argued that IoT auto-capture/sensory capability had human resource implications by reducing human intervention: *"You take it, scan it and pass it on…. No need for data entry"* [Retailer H]. Six retailers thought that IoT platform improved communication, therefore improving intra- and inter-firm relationships: *"It goes back to timely communication"* [Retailer G]; *"I think that there would be a better relationship between stakeholders if more IoT is developed because it will improve the line of communication, improve collaboration and build up trust because the kind of transparency it provides"* [Retailer C]. However, while Retailer D acknowledged the IoT's capacity to integrate business processes, they also asserted that *"oral communication matters more than the technology and the technology is just a tool to help us"*. The proposition is developed as below.

Proposition P6*: IoT adoption positively affects visibility, communication, intelligence, and automation in supply chains.*

4.10 Challenges for IoT Adoption in SCM

The principal obstacle to IoT adoption cited by 11 retailers was investment cost: *"The cost is obviously the real big obstacle"* [Retailer L]. Three participants highlighted the lack of long-term investments: *"Any such investment is seen as a liability, rather than seeing it to improve the business in the long term"* [Retailer A]. However, eight retailers explicitly asserted that IoT implementation is a sound investment, while nobody spoke pessimistically: *"The cost is always an issue, but it will pretty much offset in about three years into operations"* [Retailer E]; *"Obviously the IoT technology is not a loss-making. It is profitable if you use it correctly"* [Retailer J]. Retailers B and I argued that it was not fair that upstream suppliers and manufacturers bear the cost of technology, such as RFID, yet downstream partners benefit more. Retailer I called for collective investment: *"It is a space where retailers and brand owners need to invest together to impart improvements"*.

The next recurrent obstacles reported were internal leadership issues. One (cited by 7 participants) was that the technology was not well understood within organisations: *"If you don't see the benefit, you only see the cost. It is not the cost that is the biggest issue; it is the knowledge"*, [Retailer F]. Six managers also discussed a perceived lack of management vision in IoT adoption: *"I think there seems to be a certain level of the reluctance of investing in this (IoT) space. Decision-makers find the cost to service and operations a little bit too abstract"* [Retailer A]. Also, 4 participants felt that senior managers lacked a clear understanding of the demands of SCM. Retailer I went so far as asserting that *"managers don't want to know up the value chain, it is easy to disguise what is happening upstream"*. The issues above were exacerbated by not having good examples cited by three retailers: *"When we made the transition, we didn't have a proper example to look at, saying these guys were here, this is what they did, and this is where* *they are now. We were a bit cynical about moving forward with IoT investments"* [Retailer H].

The next set of obstacles are related to resistance from internal and external stakeholders. Six cited employee resistance to change: *"It's human behaviour, people are reluctant to change"* [Retailer L]. Four respondents felt that due to the existing challenges faced by the firm, they lacked time to learn and adapt to new technology: *"Us being a lean business and running at hundred miles an hour, having to stop and having something impact on existing processes and flows (sic), people are quite resistant to that"* [Retailer K]. Six participants cited staff members fearing technology as an obstacle, while privacy and security issues were raised by 6, particularly in relation to consumer apps: *"People are nervous about where your data is going to sit"* [Retailer H]. Three participants also identified resistance to surveillance: *"When couriers first introduced GPS tracking, there were union issues and stuff"* [Retailer K]. However, Retailer I disagreed: *"We did fingerprint scanners for staff to link to the payroll system. We did not have any resistance from the staff. The staff was very open to it. They will not resist if it makes their life easy"*.

Finally, the technology itself was questioned. Internet reliability was a concern, with Internet breakdown and coverage issues cited by three participants. Retailer L also raised the technicality of *"the integration capabilities of existing systems"*. Conversely, Retailer A felt that *"...there is a definite need for IoT deployment, then at the same time the technology is moving so fast. There is a reluctance from top management to invest in any form of technology. Because there is a fear that it would be deemed obsolete within another two years"*. In categorising the challenges for IoT adoption, the following proposition is proposed:

Proposition P7*: Socio-technical factors challenge the proliferation of IoT in SC operations.*

4.11 Constraints in Capitalising on Existing IoT in SCM

While some firms had IoT embedded in their supply chains, they were unable to fully capitalise on it mainly due to human issues. The key constraint, according to eight retailers was not having the time to explore their newly introduced IoT technology: *"A huge time needs to be spent on training yourself first and understanding it well, and then train the staff and the third-party providers"* [Retailer C]. Some participants linked this to workers' age as a constraint with adaptability to IoT technologies: *"We got a very young team, because of that, we were able to adapt quickly"* [Retailed D]. Six participants attributed particular significance to resistance from older workers: *"Sometimes they try to avoid using this, especially if they are a bit older. We have to persist and persist so that they use it"* Retailer E]. Six retailers also mentioned a reluctance to change in. Three retailers felt that low-skilled staff were not making the best out of the IoT: *"Some of our low skilled staff don't have the capacity to interact with technology"* [Retailer I]. Furthermore, not being able to properly understand IoT data was discussed as a restriction by 3 participants: *"It's a lot about understanding data, being able to digest the analytics"* [Retailer B]. Retailer H cited the complexity of having various IoT related identification technologies. *"RFID, QR codes, barcode, NFC, we have to be ready for all that"*.

Relationship with partners was also an identified obstacle, with the level of technologies of SC partners discussed by 3 participants: *"The main obstacles of making the most out of our current IoT system is, all our partners are not at par with what we have, they are behind"* [Retailer H]. According to 4 managers, information sharing was feared by partners: *"Most of the time they fear sharing. That is the biggest killer for us and the IoT as a technology"* [Retailer H].

From an Organisation Capability (OC) and a resource-based view (RBV) theory perspective, IoT application is an initiative in building up the capability to enable partner integration to enhance SC performance (de Vass *et al.* 2018). IoT *per se* is viewed as a technological capability that needs to be embedded in the logistics processes. Therefore, its entry into the SCM needs to be coupled with existing higher-order ICT capability that would likely facilitate integration, learning, and knowledge management to gain competitive advantage (de Vass *et al.* 2018; Huo 2012). In a similar vein, these constraints in capitalising on existing IoT can be explained as firms' inability to blend/integrate IoT with higher-order capabilities and SC processes. Therefore, the following hypothesis is proposed.

Proposition P8*: Firm-specific integration constraints are negatively associated with fully capitalising on their existing IoT applications.*

4.12 Interoperability, Openness and Standardisation Issues

Five participants identified not having access to the systems of SC partners as a challenge: *"If we could log into the portal of the shipper to track and trace, that saves us picking up the phone, calling, and having a 20-minute query on goods delivery status"* [Retailer A]. Having access to partners' systems, but still not having that system integrated into their own system, was also discussed by 3 participants: *"At the moment we don't have integration with Australia Post. So, when someone places an online order, we log the job with Australia Post. They send tracking information to the customer. Our order confirmation doesn't have tracking details. It should, therefore, be a singular experience for the customer"* [Retailer L]. Three retailers discussed the inefficiency of having to log into too many interfaces, as *"systems not being interconnected (silo)"*. The Retailer I argued for *"collaboration on one agreed platform"*.

Eight retailers discussed the theme of standardisation, while four retailers cited the issue of not being able to integrate systems due to a lack of standardisation. Four retailers expressed their frustration at the range of different standards of identification technologies, as well as open and closed standards: *"a minimum of three barcodes are stuck on a pallet by the time it gets inside the warehouse, one at the supplier end, one by the transporter, one by the warehouse"* [Retailer C]. Retailer I suggested a solution: *"...overall collaboration at the retailer end of the process can really assist in alleviating the burden on the rest of the SC to adopt too many different mechanisms"*. Five retailers cited GS1 open standard during interviews. Such open standards as EPC-based RFID tags, barcodes, IPv standards may address the reported drawback of interoperability among stakeholders using various IoT infrastructure, systems, and hardware (Atzori *et al.* 2010; Borgia 2014). As per the inter-firm constraints found, the following proposition is developed:

***Proposition P9**: System integration among partners, openness, and standardisation positively affect the benefits of IoT.*

5. OPPORTUNITIES, CHALLENGES AND SOLUTIONS

The IoT is becoming popular in the Australian market as the industry, particularly the retail, increasingly understands its capabilities. The RFID, being the foundation technology for IoT, did not capture the market well due to its higher unit cost, restricted use at the item level, and cost of integration into the organisation's legacy software systems and externally with suppliers and customers. However, the new generation IoT offers multiple opportunities as more ‘things’ appear as sensors and actuators to connect with mobile devices within the communication network (Ben-Daya *et al.* 2019). For example, interview findings show that smartphones are well integrated into supply chain operations, not just for customer integration, but also to increasingly help SCM staff complete multiple tasks. This consolidation of multiple devices into a single device such as smartphone effectively helps the retailers to reduce the e-waste resulting from dated electronic gazettes (e.g., multiple sensors and accessories). All retail firms participated in the study have indicated that the 3PL service providers (e.g., transporters) are the “pioneers” and “enablers” of IoT use in a supply chain. The use of GPS-enabled in-cabin IoT devices (e.g., video cameras and sensing devices) integrate the suppliers and retailers who get the real-time visibility of product movement.

While competition in retail space has pushed the profit margin down, the retailers have relied relatively more on technologies (i.e., IoT) to enhance operational efficiency. Further, higher data transmission rate (i.e., low latency 4G network), and increased affordability of sensing devices (i.e., IoT) have pushed the retailers towards IoT use. Thematic analysis reveals that IoT use has enhanced their operational efficiency, labour productivity, communication speed, process optimisations, real-time data capture for product visibility, accurate, in-depth data capture, security and surveillance. In doing so, they have ensured better visibility, auto-capture/sensory capabilities, improved business intelligence via in-depth IoT data, and enhanced communication capabilities over the traditional ICT-enabled SCM context.

Despite many opportunities that IoTs bring in retail space and their supply chains, there are numerous challenges for IoT to be effusively embraced. As we understand from the interviewees, the real obstacles to IoT adoption currently are investment cost, lack of management vision, general staff issues such as employee resistance to change and fear of new technologies. However, the majority of the retailers asserted that IoT deployment was a sound investment. This ground reality of IoT benefits, we believe, will encourage the cynics to follow the path of adoption and use. Lack of standardisation, interoperability between software systems, and unwillingness to share business data with SC partners remain as other socio-technical drawbacks behind the adoption. While capturing in-depth data at the retail level, the retailers appear unwilling to share data among SC partners, ultimately reducing their benefit from IoT adoption. However, that precise and timely information sharing through collaboration and integration of SC partners can improve firm sustainability (de Vass *et al.* 2020). Therefore, the SC partners need to cooperate with each other to reap the benefits of real-time data sharing using the IoT. Also, finding time to learn the new technologies, and understand its operational benefits remain a significant concern to capitalise on their existing capabilities. The retailers need to consider professional development of staff through training programs and allocate them time for self-learning of these technologies. This will help the retailers transitioning to Industry 4.0 era that has envisioned the IoT at the centre of cyber-physical systems in a supply chain environment. As the era progresses, technology advancement and reliable Internet connectivity (e.g., upcoming 5G network) (Taboada and Shee 2020), amidst the above challenges along with security and privacy issues, will drive the top management to embrace the IoT platform.

6. IMPLICATIONS

Although there are considerable theoretical insights in the literature, little empirical evidence for the processes, challenges, and opportunities to IoT adoption exists (Haddud *et al.* 2017; Mishra *et al.* 2016). This study, the first of its kind through case examples, attempts to address this gap via an exploratory account with several implications for academics, practitioners, and society. Reported narratives also provide proof-of-concept for Industry 4.0 SC digitalisation that could be an insight to promote future IoT investment.

6.1 Theoretical Implications

Academically, this study identifies a wide range of opportunities and challenges concerning IoT adoption and use in SCM against the hype of its benefits in literature. Although the literature conceptualises ample benefits that IoT can bring into the supply chain, it does not provide empirical proof-of-concept (Mishra *et al.* 2016; Sharma & Khanna 2020). For example, while Haddud *et al.* (2017) theoretically argue for the IoT's benefits and challenges using a survey of academics, their study is not supported by empirical evidence of implementation. The present study provides such evidence and contributes to informing and boosting managers' confidence regarding IoT implementation in Industry 4.0 digitalisation. The study also sheds light on the current status of IoT implementation within firms. Furthermore, the drivers, motives, and obstacles of IoT adoption and perceived benefits are identified and discussed in this study. Although de Vass *et al.* (2018) claim that IoT adds additional capabilities to strengthen internal and external integration of partners in a supply chain, their study did not shed light on additional capabilities such as visibility, data auto-capture, business intelligence and improved communication that IoT can offer. Also, while Hopkins and Hawking (2018) explain the application and benefits of IoT technology in a case of a transporter, the present study also provides retailers' perspectives on how they use the IoT for data capture of goods movement and their analysis for operational improvement.

The findings also indicate that willingness to share data with the trading partners is limited, in contrast with the findings of theoretical literature. Further, the issues of interoperability and standardisation in the adoption of these technologies are also revealed. If one takes a view of digitalisation and automation as a measure of effective SC performance, the study explains how to achieve the Industry 4.0 goals. Methodologically, this study develops a set of propositions for future research that could be tested in large-scale studies to enhance external validity.

6.2 Managerial Implications

Practically, this study offers insights for managers about the opportunities but also highlights the challenges behind the move. Industry 4.0-compliant smart SC is predicted to take off soon, but it is currently fragmented. The wisdom of such technology diffusion is ever more important to practitioners who are preordained to accelerate digitalisation globally to effectively manage supply chains in post-COVID-19 context (Baldwin & Tomiura 2020). Managers, therefore, need to understand the opportunities while trading off the challenges of IoT-enabled digitalisation. While challenges overshadow most firms' opportunities for IoT-related investment, this study indicates the importance of IoT adoption not to be left behind as the technology proliferates and competitors move in adoption and use. This study presents evidence of the IoT in action that may serve as an example for those who have been looking for evidence (Huddiniah & ER 2019). The benefits these retailers gain via IoT is adequate motivation for others to overcome challenges. For example, 3PL service providers are at the forefront of IoT deployment, and they are the ones that connect with retailers, suppliers, and customers. Their experience used in this study will have a stronger influence on prospective IoT users.

Retail managers must engage with 3PL services along with their technology platform to better integrate them into supply networks to enhance visibility and trade communication. Although the highly advocated ICT-enabled SC inherently relies on technology like IoT and others, the study findings indicate that retailers are unwilling to share data collected through these technologies. Retailers appear cognizant of IoT-driven real-time streaming analytics and reporting that could help them in business intelligence. However, these areas face challenges like time constraints, lack of top management initiatives, inadequate interoperability with legacy technologies and partner systems, employee resistance, privacy issues, and reliable Internet connectivity and services. While the key benefits of IoT are identified and linked to how far it's integrated to the SC (de Vass et al. 2018), this study indicates the importance of SCs needing to be proactive in adopting and integrating ICT systems rather than being reactive in a piecemeal basis. Finally, the evidence indicates that managers should consider participants' advice that it is essential to consolidate to minimise the number of devices and look for new ways to reduce e-waste leading to improved sustainability.

6.3 Social Implications

Industry 4.0 era literature claims that IoT improves SCI, which has a significant impact on sustainable performance (Ben-Daya *et al.* 2019; de Vass *et al.* 2018; Manavalan & Jayakrishna 2018). Findings encourage IoT adoption is SCM, resulting in more environmental and people friendly SCs. While reductions in staff numbers are a likely consequence of greater IoT adoption, more staff may need to be engaged in configuring and monitoring the technology. This study's findings may also encourage the workforce to develop alternative skills that are suitable for Industry 4.0. While a stream of scholars studies the impact of IoT on sustainability (de Vass *et al.* 2020), another stream looks at the negative aspect of e-waste from technology application (Alieva & Haartman 2020). Our findings indicate a drive for consolidation of devices; the lack of RFID progression for item-level identification and exploration of less appliance-dependent alternative technologies such as video analytics and smartphones may create a nexus for the two research streams. Given the prediction that this potentially infinite platform of devices could turn our planet into an e-waste dump yard, device consolidation is a positive development in that direction. Finally, the findings are an early alert that the IoT platform has linked the humans as workers or customers to the SC digital infrastructure, primarily via piggybacking through personal devices such as smartphones.

7. CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH DIRECTIONS

The study investigated empirical narratives of IoT adoption, including the opportunities and challenges Australian retailers have experienced over time. The GT was drawn upon to examine issues via loosely structured interviews with twelve retail practitioners and one 3PL firm. This qualitative study presents unprecedented insight into the drivers, enablers, benefits, challenges, and barriers of IoT adoption in SCM. The interdisciplinary study between SCM and Information Systems on the topic of emerging technology in SCM provides helpful empirical insights for researchers and practitioners about multiple dimensions of IoT adoption and use. The knowledge may guide to accelerate the digitalisation of supply chains during and after COVID-19 context. The propositions developed based on the early Industry 4.0 era findings that show the retailers' preparedness to embrace the technologies like IoT.

The study has some limitations. Although the findings fit well through the represented sample confirming the internal validity, we acknowledge that the number of retail cases (n=12) limits the generalisation of the findings. Future studies with more interviews can help identify the subtle issues and conceptual dimensions around the IoT use (Hennink *et al.* 2017). The larger sample across sectors or within a specified industry offers a better understanding of the complex phenomena, uncover more insightful knowledge given the rapid progression and complex nature of IoT in SCM context. Incorporating perspective respondents who are more familiar with IoT and its effect on business processes may add additional knowledge. The propositions developed in this study can serve as a foundation for future studies and facilitate their testing in framework-based survey research. Also, the current finding is limited to a unilateral focal retail organisation across industries. Inclusion of vertical (i.e., supplier, customer, and grower) and horizontal (i.e., 3PL, regulatory authorities) collaborators into the study will likely enhance the insights about IoT use in SCM. Future research may reveal key findings that incorporate the 3PL service providers who are believed to be progressive in IoT adoption. In addition, the IoT knowledge presented in this paper will lead to design a fully functional problem-solving research that is deeply rooted in design research paradigm (Miah & Gammack 2014).

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