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Iot in supply chain management: a narrative on retail sector sustainability

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ABSTRACT
The Internet of Things (IoT) is a global platform of Internet-connected smart devices that strengthens the supply chain ICT infrastructure for greater integration within an organisation and externally with suppliers and customers. However, the IoT literature so far remains theoretical and excessively focused on its technology and potential applications, with a very limited revelation of its operational benefits. Therefore, the study explores the ground reality of IoT impact on supply chain integration and performance. Twelve semi-structured interviews with managers from the Australian retail industry were thematically analysed using NVivo. The findings reveal that multiple IoT forms provide additional capabilities in data auto-capture, visibility, intelligence, and information sharing for greater integration of retail supply chains. That, in turn, enhances supply chain performance in cost, quality, delivery, and flexibility dimensions to improve firm financial, social, and environmental sustainability. The study outlines the theoretical and practical contributions arising from the deployment of IoT.

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Internet of Things; IoT; supply chain management; supply chain integration; sustainability; retail; industry 4.0; smart supply chains

1. Introduction

The term Industry 4.0 was coined to signify the fourth industrial revolution, a new era conceptualised as integrating the Internet of Things (IoT) into manufacturing environments so that machines can exchange information and operate autonomously in a smart factory setting (Hofmann and Rüsch 2017; Tjahjono et al. 2017). To make Industry 4.0 a reality, all processes in the supply chain must be digitalised and automated (Hofmann and Rüsch 2017; Tjahjono et al. 2017). While the cyber-physical era advances, supply chain management (SCM) continues to face the growing challenges of digitalisation while attempting to achieve the goal of sustainability in a circular economy (Dev, Shankar, and Qaiser 2020; Hofmann and Rüsch 2017; Manavalan and Jayakrishna 2018). On the other hand, organisations' traditional digital capabilities are insufficient to respond to the growing market need (Bharadwaj et al. 2013). Organisations, therefore, need to augment their capabilities (Yeow, Soh, and Hansen 2018), including those that IoT offers, as a foundational technology for transition to Industry 4.0 era (de Vass, Shee, and Miah 2018; Tjahjono et al. 2017). This paper explores the Australian retail sector and the role of the IoT within its supply chains.

The IoT is defined as an Internet-connected global platform of uniquely addressable smart devices with sensing, networking, processing, and actuation capabilities that facilitate the ability of people and things to collaborate in heterogeneous environments (Borgia 2014; de Vass et al. 2018; Mishra et al. 2016; Whitmore, Agarwal, and Da Xu 2014). The concept is a progression from the existing Internet-connected computers to a paradigm where any physical 'thing' (object) is connected to another using the Internet touch-point (node) (Borgia 2014; Whitmore, Agarwal, and Da Xu

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2014). A variety of IoT forms such as Radio-Frequency Identification (RFID) tags, sensors, handheld devices, wearables, GPS telematics, medical devices, actuators, vehicles, drones, machines, and smartphones coexist to interact with its environment as well as with each other (Lee and Lee 2015; Mishra et al. 2016). The IoT integrates a significantly higher number of network nodes than the conventional ICT (Information and Communication Technology) infrastructure ('trillions versus billions') (Hofmann and Rüsch 2017), therefore capturing, transmitting, storing and processing more transactional data by harnessing the power of the Internet (de Vass et al. 2018; Haddud et al. 2017).

Despite the widespread recognition of the potential benefits of IoT, its application to SCM, and operational (logistics) excellence have seldom been explored (Ben-Daya, Hassini, and Bahroun 2017; Mishra et al. 2016; Whitmore, Agarwal, and Da Xu 2014). The literature is mostly restricted to a focus on technology, benefits conceptualisation, and application simulation across businesses; existing research does not sufficiently demonstrate operational validity (Ben-Daya, Hassini, and Bahroun 2017; Mishra et al. 2016). A recent case study does provide in-depth insights into IoT use in transportation (Hopkins and Hawking 2018) but does not discuss its implications for application across the supply chain. Another study, by de Vass et al. (2018), finds a positive effect of IoT-enabled supply chain integration (SCI) on supply chain and firm performance. However, the survey-focused perceptual research could not provide insight into the practical application of IoT in logistics processes. Studies focusing on the applicability of IoT in SCM on operational sustainability are scarce. The vast range of technologies that comprise the IoT, its heterogeneous applications, and capabilities (Hopkins and Hawking 2018; Lee and Lee 2015), as well as the intricacy of SCI in the SCM context (Alfalla-Luque, Medina-Lopez, and Dey 2013; Huo 2012), necessitate in-depth investigation. Furthermore, since the literature on IoT-enabled supply chain sustainability in the context of Industry 4.0 is still at its infancy (Manavalan and Jayakrishna 2018), a greater understanding of how each of these technologies impacts the processes in supply chains is required,

Therefore, the objective of this study is to explore the practical applications of IoT in supply chains, and the way it affects the sustainability performance of organisations. The following research questions guide this study:

> RQ1. How does IoT implementation integrate the logistics processes of an organization internally and the suppliers and customers externally?

> RQ2. To what extent does the IoT-enabled process integration impact supply chain performance and firm sustainability?

The focus of this study is the Australian retail sector. The retail industry is at the forefront of embracing IoT (Balaji and Roy 2017) to overcome the challenges posed by its current practices and customer expectations (Majeed and Rupasinghe 2017). Given that the retailers are in direct contact with customers, digital connectivity with suppliers is particularly crucial for timely and complete replenishment of goods to ensure the availability of merchandise. The Australian retail context was deemed appropriate for the study because previous studies of the context report the co-existence of various IoT forms. For example, a recent survey-based study by de Vass et al. (2018) reveals that Australian retailers have IoT in multiple forms in their supply chains, including GPS-based location awareness, Internet-based barcode technology, sensors and scanners, palm-held tablets/smart devices, smartphones, mobile apps, and Internet-based security and surveillance, with at least a single form of IoT in each supply chain. Another study, by Hopkins and Hawking (2018), documents several in-cabin IoT technologies that truck drivers often use in road transport in Australia, such as sensors that help in capturing vehicle speed, location, braking, and engine data; truck telematics; geo-information to enable proactive alerts, and; camera-based technologies to improve driver safety and fatigue. Further investigation may reveal a range of IoT technologies that enables integration of logistic processes within a firm and with suppliers and customers to impact on supply chain and firm performance. Thus, the study's assertion that IoT may enhance the capability of retailers to integrate internal and external logistics processes is further supported by organisational capability (OC) theory (de Vass et al. 2018).

This paper begins by reviewing the background literature on OC theory, SCI, and IoT to identify the gap. This is followed by the research methodology and the reports on the qualitative findings on IoT-enabled SCI and performance. The paper then presents a discussion of the results and theoretical and managerial implications. Finally, the paper concludes with study limitations.

2. Literature review

2.1. Organisational capability theory

This study uses OC theory to argue that IoT adoption enhances the integration capabilities of retailers. The question that remains is *how* its adoption enhances this capability. Answering this question requires a clear understanding of OC theory in the context of ICT infrastructure as a means to integrate supply chain processes. Here, we utilise a claim by Rai, Patnayakuni, and Seth (2006), which states that 'a firm must develop capabilities to acquire, integrate, reconfigure and release resources that are embedded in their social, structural, and cultural context' (Rai, Patnayakuni, and Seth 2006, 227). The OC theory posits that integration *per se* is a higher-order capability that influences performance directly (Huo 2012; Rai, Patnayakuni, and Seth 2006). While ICT is often promoted as a driver of SCI, ICT is a lower-order capability to enable a higher-order integration capability (Huo 2012; Rai, Patnayakuni, and Seth 2006). ICT itself is not guaranteed to affect performance directly; instead, it needs to be blended with higher-order capabilities for performance improvement (Rai, Patnayakuni, and Seth 2006). In other words, ICT alignment with organisational business processes (integration) renders positive outcomes (Rai, Patnayakuni, and Seth 2006; Vanpoucke, Vereecke, and Muylle 2017). ICT infrastructure assists firms to integrate their internal and external logistics processes for sustained performance gains (Rai, Patnayakuni, and Seth 2006).

As organisations adopt technologies into their operations, they seek to integrate various functional areas and processes internally and externally with suppliers and customers (Huo 2012). On the other hand, it is the inherent capability of IoT to sense and collect data through object-to-object interactions that entice retailers to adopt its constituent technologies (de Vass et al. 2018). When data captured at the level of retailers is shared with suppliers, it enables the retailers to manage the inventory efficiently. So, the IoT-enabled integration of processes between the business partners improves the capability of retailers to respond to the market need quickly in a cost-effective way. The existing literature posits that the IoT provides additional capabilities beyond traditional ICT infrastructure (Ben-Daya, Hassini, and Bahroun 2017; de Vass et al. 2018). Such capabilities refer to the ability to sense, auto-capture, transmit, and make the data visible locally within an organisation and with others externally. Its application improves security, value, connectivity, intelligence, and telepresence (Nabeeh et al. 2019). Via real-time tracking, the IoT enhances the visibility of goods that flow in the entire supply chain to balance the resilience and flexibility at the right cost (Ben-Daya, Hassini, and Bahroun 2017; Manavalan and Jayakrishna 2018). Thus, IoT-enabled integration can be viewed as an OC that IoT brings into the retail environment (de Vass et al. 2018; Huo 2012).

2.2. Supply chain integration and performance

Business processes must be designed, managed, and coordinated as a single entity to achieve a better competitive advantage (Alfalla-Luque, Medina-Lopez, and Dey 2013; Ataseven and Nair 2017). SCI conceptualises synchronising business processes by inter – and intra-firm management of materials, funds, and information flow to provide the highest value to customers at the lowest cost and the topmost speed (Alfalla-Luque, Medina-Lopez, and Dey 2013; Shee et al. 2018). SCI improves visibility, traceability, interoperability, and collaborative decision-making to maximise supply chain performance (Reaidy, Gunasekaran, and Spalanzani 2015). Earlier empirical evidence confirms the positive impact of SCI on performance (Alfalla-Luque, Medina-Lopez, and Dey 2013; Ataseven and Nair 2017; Kim 2013; Vanpoucke, Vereecke, and Muylle 2017). A multi-dimensional approach (internal, supplier, and customer integration) of SCI (Alfalla-Luque, Medina-Lopez, and Dey 2013; Ataseven and Nair 2017; Yu 2015) has a direct or indirect effect on performance (Huo 2012). Internal integration breaks down functional silos and facilitates collaboration within a firm. For example, supplier integration has been found to improve collaboration between firms and their suppliers by managing cross-firm business processes, while customer integration has been found to strengthen downstream linkages for a deeper understanding of market expectations and opportunities (Huo 2012; Yu 2015). Furthermore, internal integration serves as a foundation for establishing external collaboration (Kim 2013).

In fact, ICT plays a central role in enabling SCI that facilitates information exchange in the supply chain (Liu et al. 2016; Shee et al. 2018; Vanpoucke, Vereecke, and Muylle 2017) by acquiring, transmitting, and processing data (Ben-Daya, Hassini, and Bahroun 2017). ICT strengthens the relationship between SCI and both operational and financial performance (Liu et al. 2016). The interaction between the digital and physical world continues to increase the information exchange, making contemporary SCM difficult if ICT is ignored. Further, studies find that ICT alone does not affect performance directly, but enhances performance by strengthening SCI capabilities (Li et al. 2009; Rai, Patnayakuni, and Seth 2006). It is important to note, however, that most SCI studies are survey-based, grounded on generic ICT infrastructure, and that the significant contribution of emerging technologies such as IoT is largely not adequately discussed in the SCI context (de Vass et al. 2018; Vanpoucke, Vereecke, and Muylle 2017).

2.3. IoT and supply chain integration

IoT connects billions of objects and devices to provide valuable opportunities for businesses (Abdel-Basset et al. 2019b). The pervasive presence of the IoT has severely disrupted the way societies access and exchange information and interact with their surroundings (Borgia 2014; Lee and Lee 2015). The supply chain is no exception when it comes to IoT adoption. Although the term IoT was first coined for RFID and used sparingly, the concept has evolved to include embedded technology in any physical object, generating far-reaching capabilities and eclectic diffusion (Borgia 2014; Mishra et al. 2016). As a new genre of ICT, IoT functions as a superior conduit between the physical and digital worlds (de Vass et al. 2018; Ping et al. 2011). Further, the limitations of traditional ICT have paved the way to this powerful platform of things (objects) with a unique identity, pervasiveness, sensing, automation, intelligence, and communication capabilities (Constantinides, Kahlert, and de Vries 2017; de Vass et al. 2018). Despite the early stages of its inception in various forms, the pervasive presence of IoT devices is reported to conduct real-time monitoring of almost every link in contemporary supply chains, enabling a seamless flow of information and goods (Ben-Daya, Hassini, and Bahroun 2017; Hofmann and Rüsch 2017). While the IoT was first coined to track items along the supply chain, its various forms, such as sensors, personal digital assistants (PDA), and smartphones, enable SCI that facilitates information exchange and physical flow (Ping et al. 2011; Yan et al. 2014).

We define IoT in the supply chain context by consolidating the definitions of various authors (Ben-Daya, Hassini, and Bahroun 2017; Constantinides, Kahlert, and de Vries 2017; de Vass et al. 2018; Haddud et al. 2017; Majeed and Rupasinghe 2017). IoT, therefore, is defined as an Internet-connected platform of pervasive smart objects that can identify, sense, process, actuate, network, and share data for timely planning and coordination of logistics processes within an organisation and between supply chain partners. This definition has key features like digital connectivity between objects, organisations, data capture, sharing internally and externally with suppliers and customers, and the ability to integrate all in a supply chain.

Studies at the intersection of the IoT and supply chain management are quite limited. Linton (2017) points out that with 2.5 million academic journal articles published to date on technology, a smaller quantity (20,670) is on emerging technologies, and only 67 articles include both emerging technology and SCM. Also, the literature review undertaken by Ben-Daya, Hassini, and Bahroun (2017) indicates that the IoT in the SCM context is only conceptualised with minimal empirical or exploratory studies. Abdel-Basset et al. (2019b), via a case study, find that communication, technology, privacy, and security are some of the challenges of IoT deployment in businesses. Ping et al. (2011) rationalise how the IoT bridges the gap between physical and digital worlds by synchronising the material flow with the information flow for improved SCI. Yan et al. (2014) tested an IoT architecture in controlled laboratory conditions to confirm its SCI capability. de Vass et al. (2018) present survey-based empirical evidence of IoT capability as having a positive and significant effect on the internal, customer, and supplier integration for performance gains.

However, survey-based empirical generalisation is criticised for its over-simplification of reality (Wieland and Wallenburg 2012). Therefore, the demand for qualitative methodologies is rising (Wieland and Wallenburg 2012). Also, multifaceted, intricate, and enigmatic phenomena of process integration in an IoT environment necessitate qualitative investigation that warrants open questions to explore relevant themes. However, very little is known about the IoT in SCM via interview-based qualitative narratives. A title search of peer-reviewed journal articles revealed 7,537 academic articles in peer-reviewed journals on ‘Internet of Things’, and only 60 titles containing both ‘Internet of Things’ and ‘supply chain’. While a recent single case study was found investigating the IoT in the logistics context (Hopkins and Hawking 2018), it did not consider the IoT for logistics process integration in retail operations. So far, vague evidence in real-life situations of IoT deployment in industry context has led to confusion surrounding its benefits (Nabeeh et al. 2019). While supply chain sustainability has drawn the attention of both academics and practitioners, information gathering to measure the supply chain sustainability has been traditionally challenging (Abdel-Basset et al. 2019a). Although the IoT provides a realistic solution (Manavalan and Jayakrishna 2018), the literature lacks the real-life proof of the IoT’s impact on retail sustainability. Therefore, this research seeks to address this gap using an exploratory study on how IoT can integrate processes internally and externally with suppliers and customers to improve the sustainability of the retail sector.

3. Methodology

This study is designed as exploratory research because the phenomenon under investigation is at its early stage of maturity and not well understood in the literature (Ardolino et al. 2017; Yin 2017). The literature so far offers a broad conceptualisation of technology, architecture, and discrete application (Ben-Daya, Hassini, and Bahroun 2017). An in-depth interview approach was deemed appropriate to extend this conceptualisation by deductively exploring the contemporary use of IoT technology from a sample of retail firms across Australia. One-on-one semi-structured interviews with a key representative (i.e. senior manager or retail owner) from twelve retail firms and one third party logistics (3PL) service provider lasted for around an hour each. The 3PL service provider (3PL-X) was included because the participating retailers asserted that 3PL services were the key in logistics operations and remained at the forefront of IoT deployment. The 3PL, however, was not considered as the key unit of analysis in this study and was therefore used as supporting evidence of IoT uses for the retailers. The subject retailers were recruited from a list of participants in a prior study, who volunteered to participate in the interview. Individual informants were selected due to the high likelihood that their positions within the retailers would require knowledge of technology applications in logistics operations (Brinkman 2013; Olson 2016). Discussion of sample size in qualitative research is extensive in the literature (Sandelowski 1995); while the total sample size of 12 retail interviews may appear small, such a limited sample lends itself well to the purpose of this research to undertake an initial exploration of the experiences of firms and managers within them in implementing IoT in their supply chains. Rather than analytical generalising *per se*, this exploratory paper aims to capture every day ‘complexity, nuance, and dynamic’ (Emmel 2013) of IoT in SCM and sustainability.

We followed the guidelines offered by Olson (2016) and Brinkman (2013) to establish a procedure for interview preparation, participant selection, pilot testing, research questions, follow-up questions, conducting the interviews, and interpretation of data. The interview schedule was designed to explore the IoT technologies in practice and their operational impact. Those open-ended questions allowed the participants to engage in an unrestricted manner to share their experience with IoT use. The interview schedule had fifteen questions under two sections. Section one was designed to understand the firm, its supply chain, and the informant. The informants were probed for their understanding of the IoT before providing them with a broad explanation of IoT technologies that fit under the IoT concept. Section two explored the IoT technologies as they were deployed in-house, supplier, and customer-related business processes and if they had yielded any observable performance outcomes. However, the impact of IoT on supply chain performance and firm sustainability *per se* was perceptual because it was hard to segregate the contributions that come from the IoT. The supply chain performance was probed under traditional cost, quality, delivery, and flexibility dimensions, and firm sustainability was assessed on economic, social, and environmental aspects. The wording of the questions was cautiously screened to reduce social desirability bias that may lead informants to answer favourably to the questions (Nederhof 1985). Three pilot interviews with practitioners initially verified the relevance of the questions, sentence clarity, and content validity. Feedback resulted in the refinement of the interview questions.

3.1. Thematic analysis

The interviews with twelve retailers and the 3PL were transcribed and analysed using a typical coding process used in qualitative research (Creswell and Poth 2017; Yin 2017). The personal and firm identifiers were removed from the transcripts, and pseudonyms were assigned. The study used Braun and Clarke's (2006) guidelines for coding, which include six phases of thematic analysis: (1) familiarising oneself with the data; (2) generating initial codes; (3) searching for themes; (4) reviewing themes; (5) defining and naming, and; (6) producing the report (Braun and Clarke 2006, 87). They also suggest that the thematic analysis is not a linear, step-by-step process, but a recursive process with back and forth movement. NVivo 11 helped to categorise, group, organise and manage data to identify themes, sub-themes, and their relationships. Phases 2 and 4 led to the consolidation of thematic codes. Open coding, as discussed by Yin (2017) and others, entails the identification of themes through direct engagement with the text, while 'theoretical' coding entails the identification of themes through the literature prior to engaging with the text (Braun and Clarke 2006). This deductive, or 'theoretical' thematic analysis mostly focused on a 'top-down' way on research questions; however, a 'bottom-up' data-driven open coding was used to understand new themes (Braun and Clarke 2006). The coding process was repeated twice to reduce and refine codes. Topic coding was classified as per the key theme (Richards 2014). Predetermined themes such as IoT-enabled supplier, internal and customer integration, supply chain performance under cost, quality, delivery and flexibility dimensions, and firm sustainability under economic, social, and environmental dimensions correspond to topic coding. Under each theme, sub-themes emerged. Additional capabilities of IoT in the supply chains theme was data-driven and identified under analytic coding (Richards 2014). The coding was cross-checked, and a consensus was reached by engaging an independent coding conducted by an alternative researcher (Ardolino et al. 2017). The codes were reviewed, and overlapping codes were consolidated into broader groupings to avoid repetition. Patterns and relationships were identified across the data (axial coding).

4. Findings

The sample comprised twelve sectors of retail business that fall under the ABS (Australian Bureau of Statistics) classification of retail industry segments. The majority (seven) of the informants were from large retailers (>200 employees, as classified in the ABS), and the rest (five) were mediumsized (20> & <200). The informants have worked for their organisation for a minimum of 2 years to a maximum of twenty years, while IoT adoption varied from less than two years to over fifteen years. The retail form included brick-and-mortar to e-tailing, and omnichannel. Overall, the sample represents a good cross-section of the retail industry. Table 1 illustrates the profiles of each retailer. In the table below, the retailer is used rather than the respondent manager. The retailers' identity is decoded for anonymity and coded as A to L.

All thirteen managers (including the 3PL-X) demonstrated a good understanding of IoT applications and corresponding theoretical conceptualizations. Retailer-I stated that 'it is an umbrella term used universally where the devices capitalize the power of the Internet'. While Retailers G, E, H asserted that their supply chains were somewhat ahead of competitors with IoT deployment, Retailers A, F, L thought that they lagged behind competitors. Importantly, they all claimed to have IoT technologies deployed to a reasonable degree, either as a mix of 'things' across the supply chain or in logistic processes with different intensity. Many referred to retail as 'very competitive' and IoT as a tool to counter the competition. All praised the impact of IoT on their supply chain operations. For example, Retailer C asserted that 'IoT is a technology that enhances communication within the supply chain and gets [*sic*] the integration better'.

4.1. The existence of IoT in Australian retail supply chains

Various technologies narrated under the IoT umbrella were found to coexist in supply chains, reinforcing their digital capabilities. For example, RFID was found at unit-level (i.e. pallet, container) in warehousing and transportation. Bar-codes scanners, PDAs, RF (radio frequency) scanners, Laser, LED scanners, and camera-based scanners were widespread. In warehousing, hand-held devices (PDAs, RF scanners) facilitated picking orders and confirmed the product through scanning. Also, voice-picking (an Internet-connected voice instruction and recognition system) and automatic guided vehicles (AGV), such as an automated pallet mover or conveyor control systems, were in widespread use. In a retail store environment, hand-held sensors and devices, point-of-sale (POS) devices, video analytics (facial recognition for customer recognition and context-aware offers), IP Cameras, bar-coding (unique for perishable items) and mobile payments, including Apple-Pay, were in use.

Table 1. Summary profile of subject retailers*.

ID	Code	Work exp.	Job role	Retail sector	Key retail form	Firm size	First adopted 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 ago
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
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 ago
9	I	5 yrs.	Supply chain manager	Supermarket	Bricks and mortar	Large	10+ years ago
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 counted as the unit of analysis.

In the transport sector, the findings reveal that IoT-enabled track-and-trace systems, fleet control, vehicle tracking, and route optimisation were in widespread use. IoT retina scanners and facial recognition onboard were employed to monitor driver fatigue by tracking pupil size, blink frequency, facial expressions, and driver behaviour. IoT engine monitoring technology was also present and used to report vehicle emissions and idle time, while sensor networks in cold-chain logistics track-and-trace temperature-sensitive products. In the food industry, the customer can log into a portal on their smart-phone to order, pay, and track deliveries. In general, informants stated that delivery tracking provision for customers is considered an industry standard.

Smart-phones were found to be widely exploited. The findings identify the retailers' drive to consolidate multiple devices, mainly towards the multi-faceted smart-phone. Notably, informants expressed the view that real-time streaming analytics and reporting is a significant advancement driven by IoT. While all subject retailers have outsourced their logistics functions (i.e. transport, warehousing), 3PL operators came across to the researchers as early IoT adopters, with most retailers gaining their first IoT experience via 3PL transporters.

4.2. IoT-enabled supplier integration

Perceiving that IoT deployment has improved their upstream supply chain processes, all informants were affirmative on the vital role of IoT in the supplier integration space. Retailer E stated that 'these devices play a big role by bringing together our suppliers and us'. IoT plays a critical role in improving suppliers' operational and information management, communication between suppliers and retailers, forecasting, inbound delivery, receiving, and traceability.

Ten retailers explained that IoT technology helps suppliers fulfil retailers' inventory stock requirements using critical information. Hand-held devices, scanners, label-makers, QR-code, and bar-code label-makers and readers, Near Field Communication (NFC) devices, smart-phones, tablets, beacons, various sensors in manufacturing and warehousing environments, image recognition, scan-picking, and voice picking systems are some of the commonly deployed IoT forms for information collection and exchange. For example, Retailer H explained how AGV systems have improved warehouse efficiency and how the stock-take process optimisation improved via image recognition. Their suppliers' AGVs move with cameras that scan bar-codes of goods on its path to improve the accuracy and efficiency of the stock-take. Retailer F articulated that the IoT helped their suppliers better understand their manufacturing processes by evaluating the performance of machines, energy consumption, ambient conditions, the status of inventory, the flow of materials via data captured by a range of sensors, hand-held devices, and RFID.

Most retailers (eight) reported that IoT facilitated communication with suppliers for stock ordering and upstream information exchange. Retailer E selects items using a smart-phone app (application), and the order is transmitted to the supplier. Eight retailers mentioned improved forecasting processes in procurement. As per Retailer G, due to IoT data, they could provide 'visibility' (forecasting data) of customers to their suppliers around two years in advance.

The common theme in upstream integration was the role of IoT in the inbound delivery process. Their transporters utilise IoT forms such as GPS telemetry to find locations, track-and-trace vehicles, fleet controlling, route optimisation, and consolidation. The 3PL-X corroborated that they provided a full track-and-trace portal with ETA (estimated time of arrival) that updated along the entire supply chain. Seven retailers voiced the same about international freight tracking. Three retailers (corroborated by 3PL-X) spoke of cold-chain monitoring where they knew the exact temperature throughout its journey to their DC (Distribution Center). Retailer C stated that 'If the temperature is off, we are going to get an alert. Probably that truck won't even reach us'. Retailer B explained the inbound process and how different IoT forms were utilised.

> As the product lands in Australia, our hand-held devices alert us what container's being picked up, weights, VGM (Verified Gross Mass), and whether it carries dangerous, hazardous goods. We then plan the delivery.

> They have automated gadgets in their trucks to know the weights remotely. When they deliver it to our DC, geofence around the DC says it has arrived.

It was echoed that more drivers used sign-on-glass devices, instead of paper run sheets, so that the data transmission was in real-time. Retailer G summed up by saying that 'there are many IoT technologies throughout, working together until we receive it'. The IoT in receiving was a theme discussed by nine retailers. Retailer C claimed that efficiency in receiving had improved owing to hand-held devices and machines connected to the IoT. Upstream traceability was another theme discussed by four retailers. The 3PL-X also corroborated that they perpetually maintained a history of IoT data that they resorted to in case of an incident. However, the role of IoT in traceability beyond the first-tier supplier was only discussed by Retailers A and I, where Retailer I also brought up the potential of IoT and Blockchain integration in this space.

4.3. IoT enabled internal integration

While eleven retailers acknowledged that IoT had improved their internal logistics processes, Retailer K disagreed and emphasised that their business model did not need such integration. However, the consensus of in-house process improvement was that IoT had improved internal integration in these select cases. Retailer H conveyed that 'these technologies have streamlined our internal operations' and clarified that the 'IoT reduces data entry errors and report generation is instant'. Retailer L explained that 'going paperless' improved their operation via autonomous updating and better integration with online systems. Major themes discussed were around DCs/inventory, retail stores, and HR operations.

The most common theme, which was only omitted by Retailers E and F (having no in-house DCs), was the perceived role of the IoT in DCs. Retailer A explained how efficient the picking had been using hand-held devices; such devices were found to be commonly used in warehousing and DCs to support the receiving, slotting, picking and dispatch, or in cross-docking and split-to-zero. Retailer C mentioned a hand-held device, termed MDT (mobile data terminal), that helped them in receiving, product identification, and retrieval using bar-codes, right from receiving until replenishment. Some retailers undertook location picking via voice-pick systems. There are several sensor technologies positioned to reduce electricity usage, which is one of the highest expenses in warehousing. Production of real-time data, reduction of inventory, increased productivity, process optimisation by increased speed and efficiency, and reduction of human involvement and staff numbers were found to be outcomes of IoT use in warehousing. Retailer H added that

> office administrators used to enter inventory data. When it goes into the system, and by the time we find errors, it will be about two days. But, now it's just a matter of scanning the item, and the system gets updated.

Data accuracy due to minimised human intervention, improved safety due to reduced staff numbers on the floor, and safety measures via sensor technologies were also identified as benefits by informants. Others included security and surveillance, energy savings, convenience, and fingerprint scanning for payroll purposes.

Except for Retailers A (no in-store IoT) and L (e-tailer), the other retailers discussed IoT driven in-store technology positively. The POS devices and various hand-held devices that incorporate bar-code technologies are standard in retail stores. Retailer B explained the PDAs' ability to remotely scan item bar-codes to retrieve price and information, prepare price change tickets, and print labels instantly via a miniature Wi-Fi connected device. Retailer C further had their reports and orders autonomously generated via scanning of products during movement. Retailer I highlighted how self-checkouts had increased their operational efficiency, while six retailers mentioned generic Internet-worked POS bar-code scanning devices. Retailers C, D, H, and I have smart-phone apps with autonomous reporting on sales progress, inventory, sales by state, including Planograms (visual representations of each retail store's products), and alerts in real-time shared by cross-functional teams.

Retailer D said, ‘Everyone looks on our smart-phone app to monitor sales. That’s been really helpful for communicating the performance of our stores to everyone in the business’. Retailers D and I spoke of the Internet-driven (unique) bar-coding technology, while Retailer D detailed their need for such outer cutting bar-codes, ‘to be much faster in receipt of goods within the store’. Retailer G stated that they were currently bar-code driven. Still, their global team was contemplating moving on the direction of RFID soon to improve the accuracy of data communication and service levels.

Hand-held devices were found to serve a multiplicity of purposes, including four retailers explicitly mentioned using them in stock-takes. Retailer J explained that ‘RF guns are multitasking, used for stock-take, takes and sends photos, panic buttons’. Retailer J, representing a fuel retail business, spoke of a unique IoT application. Their underground fuel tanks have sensors fixed to track fuel levels. The sensors feed in-store computers, as well as the central operations. These sensors send alerts in an unusual event such as theft or when the fuel goes below a determined (analysed in real-time) level, to remotely dispatch the next fuel trip. The manager explained that their pricing department remotely controlled the price of fuel pumps and pricing display screens. Even their printer cartridges are monitored offsite and replenished.

Retailer E believed that IoT had revolutionised the restaurant industry, for example, by using iPads to take orders. The restaurant owner further went on to discuss their reconciliation system, where they register the receiving stock using an app connected with supplies and POS system data to identify stock-in-hand and even profit and loss for the day in real-time. Even fridge temperature is remotely monitored and controlled via smart-phones. Retailers C and I employ this practice too. Retailers G, K, and J have incorporated motion tracking in surveillance, while all others use traditional remote video surveillance. Retailer E has its cash register connected to monitor sales progress remotely, enabling to compare with video to inspect if the staff is correctly entering transactions. Retailer H praised the vast progression in image recognition due to the IoT, which they were testing to examine shelf availability, as an alternative to RFID.

The key benefits of the IoT as an in-store technology reported by all informants were improved inventory accuracy, real-time information for ordering and planning, reduced in-store inventory, efficiency improvement, productivity, and labour savings due to reduced human intervention. Retailer F expressed that IoT helped improve overall stock availability, meaning that they could ‘focus more on providing customer service, rather than worrying about inventory’. Implementation of IoT devices for identification, tracking, payroll, and access control was identified as a growing trend by seven managers. Four of them employ FOBs (keyless entry devices) in accessing different areas. Retailer L spoke of having fingerprint scanners connected to payroll systems. Retailer K (in security and surveillance technology trade) stated that they used facial recognition (one of their products) for access control. Advantages of such Internet-connected applications were narrated as the ability to identify digitally, record, monitor, track-and-trace each register entry in a central database, and centrally update new identities for all scanners simultaneously.

Interestingly, only three Retailers (B, C, D) cited secondary inbound logistics operations (movement of goods from DC to retail stores). Nonetheless, they all spoke of the role of IoT in this space positively. Retailer C said that ‘we use IoT devices in our trucks for planning and safety purposes. We track if they take the designated route within the speed limit or any idling time’.

The majority (except Retailer G) thought their DCs had the further potential to improve via IoT deployment. Looking to the future, Retailer K discussed motion tracking by surveillance to record evidence on breach of parameters and alert. Retailer H plans for safety cameras with image recognition and image recognition technology capable of identifying inventory as one drove (or drone) to update inventory data. Retailer L reflected that their manual DC operations drove inefficiencies and foresaw that IoT would improve inventory management ‘exponentially’, emphasising their need for a system that provides accurate real-time information.

4.4. IoT enabled customer integration

Retailers unanimously believed that IoT is a platform for them to connect and better serve their customers. For harmonised downstream process improvement, IoT improved customer integration in select cases. Retailer G said that 'In retail, we interact directly with the consumer. If we can get the right data and communicate effectively, that converts into better service levels for the customer'. Retailer E added that, 'it [IoT] has been a good progression, as lots of new applications coming in, especially when it comes to customer-side applications'. Major themes reported under customer integration were in-store applications, understanding customers, promotions, improving online presence, picking and dispatch, deliveries, receipt, and improve ratings.

Except for e-tailer L, all others articulated that IoT in-store applications facilitated customer interaction in brick-and-mortar retail. Bar-coding and POS devices improved speed, and nine retailers discussed convenience for customers. Retailer I revealed that self-checkouts made it fast and convenient for customers. Retailers C and I articulated that individual item (unique) bar-coding on pricing perishable products (i.e. meat, deli products) improved the speed and convenience of POS check-outs for customers. Five retailers mentioned that item-level RFID would help reduce checkout time, as 'customers don't like waiting'. Retailer J described their piloted self-checkout phone app: '

> you take your stuff, scan them and put them in the basket and walk out'.

Product availability due to real-time data, thus lost sale minimisation, and customer retention was a theme discussed by six retailers. Retailer F revealed that 'when customers don't get to open up their shiny new phone straight away, they get disappointed. It is called 'unbox therapy'. We cannot have products unavailable in our stores'.

How digital payment methods have reduced hard currency circulation was the next important theme discussed by seven retailers. Retailers spoke of EFTPOS (Electronic funds transfer at point of sale) machines encouraging digital currency (rather than carrying cash), and now the wireless versions making EFTPOS even more convenient. Retailer G asserted that 'EFTPOS machines are progressively providing a seamless service'. Some spoke of evolving EFTPOS technologies from magnetic strips in bank-cards to pay-wave via an electronic chip (tap and go options via NFC), while some cited payment via smart-phones (such as Apple Pay) and smartwatches. Retailer J described a recently introduced app by a competitor that enables customers to pay for the fuel at the pump rather than going inside the store. Retailer C and I explained an IoT-based image recognition used in their car parks to combat vehicles exceeding the parking limit.

Seven retailers discussed understanding customer needs via the in-depth data captured by IoT devices. Combining POS data with reward cards to analyse the demographics of their customers was addressed by four informants. Retailer G analyses data from 'people counters' (who comes in and out) and 'sale-through information' (products they buy) with demographics (age group) facial recognition. Retailer K corroborated that many retailers have purchased such systems from them to analyse customer buying behaviour.

Eight retailers spoke of smart-phones as a medium to reach customers by helping customers find retailers and retailers to promote products. Retailer L pointed out that 'IoT definitely helps us reach customers, given everyone has smart-phones now and having access to Internet 24/7'. Another key theme discussed by six retailers is IoT location awareness, specifically on smart-phones, helping them find the nearest (or specific) store locations and providing GPS directions to get there. Retailer J mentioned the promotion of a different kind, which is an app that enables price matching by checking the fuel prices around the area. Retailer D's customers can use an app to track their loyalty points and discover store promotions. Retailer G revealed that their centrally managed IoT-based facial recognition system demographically (age group, gender) customise in-store product advertisements. Retailer K explained the scenario as 'if a kid walks in, the nearest advertising screen will display a kids meal' and confirmed that they (as IoT product for retailers) had installed facial recognition to influence customer behaviour in many retail environments.

The way customers find products and place orders, is another essential sphere influenced by IoT application, as reported by six informants. Retailer E articulated the view that the restaurant industry is intensely disrupted by IoT, primarily owing to self-ordering. In-store, they provide iPads for customers, improving sales due to customers being able to make multiple orders at any point. The restaurant also has its smart-phone application for customers to make orders remotely. Four retailers highlighted the prevalence of third-party apps (i.e. UberEats) that connected retailers, customers, and deliverers, providing purchasing options, taking orders, charging, and organising the delivery (4PL model).

When an online order is received, how IoT ensures accurate and timely picking to enable speedy dispatch is a theme cited by four informants who conduct online sales. Retailer A expressed the view that the customer's primary objective is to receive their delivery in full and on-time (DIFOT); thus, the technology to support this is necessary. Retailer H described how IoT hand-held devices enable timely, accurate dispatch, while autonomously notifying the progress to the customers. Retailer D stated that their biggest challenge was their dispatch not being efficient enough, thus negatively affecting their online sales. However, with the current system that incorporates various IoT technologies, they have been able to improve their processes, so that when the customer places an order, the system goes around in a dynamic process to find the closest store, where the order is best available, closest to the delivery route and the cheapest freight rate, then their held-held devices assist store staff pick the order quickly and notify deliverers to pick-up.

Eight retailers affirmed that IoT improve their customer-order delivery process. All had their downstream delivery process outsourced. Retailer D explained their delivery tracking process as 'the couriers track the delivery from our doorstep, right to the customers, so the customer and us both can track it via a portal. There will be a progressive real-time notification to the customers and us'. When it comes to delivery, six retailers discussed visibility as a key IoT benefit. Retailer K explained that, 'overall, I would think that it improves customer service levels, as we can see what is happening with their package in real-time'. Retailer E asserted that with app-based (4PL) food delivery services, customers could track their delivery at all times, and 'customers love it' as the process is much more convenient. Six retailers cited 'automated alerts' at critical points during the delivery process. Retailer H claimed, 'back in the day, it was hard to track an item ordered from overseas or even from within Australia. However, now, one can track and be alerted from the source to customer'. Providing good route options for deliverers was another critical feature discussed by four retailers. Shorter/optimised/best-route, retrieving optimised destination sequence, avoiding traffic, order consolidation, and efficient movement were some rewards identified within this theme. 3PL-X also corroborated that such technology was in use in delivery optimisation. Retailer F asserted that delivery is an area they could improve with IoT; they had no such integration and visibility until the supplier manually entered into the system.

Five retailers raised the theme of IoT as a platform to receive (or improve) customer ratings. Retailer H claimed that 'the best thing of this pervasive computing is ratings and reviews. It has provided a convenient platform for people to rate and review us'. Retailer E described that the restaurant industry is very much review-based. When a customer visits a restaurant (or any other establishment), search engines identify them through their smartphone's location awareness and request that customers rate the place. Further, when a (4PL) food delivery service makes a delivery, the restaurant, the products, and the driver can be evaluated via the app. All retailers agreed that smartphone presence increases the extent of ratings.

Despite the heterogeneous nature of the downstream operation in various businesses, one theme that unanimously emerged was customer satisfaction. The four fundamental aspects the retailers mostly relied on the IoT for were understanding customer needs, promotions, suggestions on what customers should purchase (to influence customers), improving customer satisfaction, and finally encouraging reviews and the improvement of ratings.

4.5. Additional capabilities of IoT in supply chains

The capabilities advanced by IoT can be themed under visibility, auto-capture, intelligence, and improved information sharing and collaboration. The critical value addition identified by ten retailers included enhanced visibility in supply chains owing to its pervasiveness. Retailer G stated that 'it is visibility at every point of the supply chain … it will tell you exactly where our product is'. More importantly, six managers emphasised its *real-time* visibility aspect. For example, Retailer H highlighted that 'everyone is looking at getting real-time information into the system. That's why IoT is so important for us'. Seven retailers highlighted how IoT devices auto-capture data, therefore reducing labour requirements. As Retailer H explained, 'now, you take it, scan it and pass it on. This is a seamless process. Earlier, they had to fill a form, and someone else did the data entry'. Ten managers highlighted higher intelligence for decision-making due to analysing in-depth data captured by IoT devices. Specifically, five managers spoke encouragingly of real-time streaming analytics of IoT data for immediate action/reaction. Moreover, six retailers established that having IoT devices linking their supply chain entities and having extra data available has improved information sharing and communication between the firm and its suppliers for greater collaboration. Retailer C reinforced, 'IoT is enabling us to communicate better with 3PLs, customers or supplies'.

4.6. How IoT-enabled supply chain integration affects supply chain performance

All twelve retailers (and 3PL-X) were positive about the outcomes of IoT deployment, as well as its potential to improve supply chain performance. The critical performance outcomes can be grouped under operational performance dynamics of cost, quality, delivery, and flexibility. Cost reduction is a crucial performance dynamic, addressed by all except Retailer I, who thought that the cost of the technology investment offset the savings. Retailer E said, 'IoT use definitely reduced overall supply chain cost … … .it can reduce the cost of the suppliers, their delivery cost and also our operational cost'. Under cost savings, efficiency (ten retailers), productivity (nine), optimisation (eight), time-saving (seven), energy-saving (six), inventory reduction (five), and reduced wastage (three) emerged as key sub-themes. All retailers cited quality improvement but under various aspects. Service quality (ten retailers), accuracy (eight), customer service (eight), convenience (six), safety (five), and product quality (five) were the key sub-themes. Nine retailers cited the delivery standard as a key dimension. Retailer A felt that 'location-based technology not only improves the efficiency of the delivery but also delivers to the precise location, improving delivery quality and accuracy'. Retailers articulated delivery speed (five retailers), accuracy (four), timely deliveries (four), and responsiveness (three) as sub-themes. Nine retailers reported that the IoT provided them with more operational flexibility. Retailer H explained that 'it improves flexibility because you get everything live, so you have time to do different things'.

The findings from the retailers' perspective of these select cases suggest that integration of IoT devices to logistics processes improves the cost, quality, delivery, and flexibility dynamics of their supply chain. While 3PL-X explained how their IoT deployment had affected the performance dimensions and emphasised on those benefits that were passed on to their clients (retailers) to win and retain contracts.

4.7. How IoT-enabled SCI impacts firm sustainability

All retailers reported a positive effect of IoT-enabled SCI on the triple bottom line of firm sustainability. They (including the 3PL-X) agreed that IoT deployment in logistics processes affects their economic outcomes positively. Retailer E was fully confident that 'there is a financial gain in using these technologies'. Many informants reported that the IoT helped directly or indirectly in company growth (eleven retailers), cost reduction (nine), sales growth (eight), customer satisfaction (six), lost sales reduction (six), consumer trust (five), customer retention (four), brand reputation (four), the return of investments (four) and competitive edge (four). Retailer H stated, 'we assume that we are finding information faster than anyone else and obviously gives us the edge over competitors. It is all about who takes the next move first'. Retailer I articulated that the integration of technologies such as IoT and Blockchain could improve brand integrity, credibility, and brand trust through improved communication and transparency. Also, seven retailers agreed that various forms of IoT applications helped their 3PL providers minimised their charges of logistics services. Retailer C supported with 'a reason that 3PLs can give us such low prices as they use these technologies for efficiency'.

Environmental sustainability was an outcome reported by all retailers and 3PL-X. Retailer G highlighted that '[IoT] is a big part of us being an environmentally sustainable company'. The impact of IoT on environmental sustainability was diverse, with reduced use of paper as the most frequent (nine retailers) theme, followed by reduction of carbon-footprint (six), electricity-saving (six), and waste minimisation (three). The 3PL-X commented that 'putting these technologies [into use] is a way we can reduce our emissions and reduce our negative impact, which is very important in transport and warehousing. As per the chain of responsibility, it finally impacts our clients (retailers)'.

Eleven retailers (and 3PL-X) revealed the social impact of IoT deployment. Retailer F stated, 'IoT has done lots, and the potential is more in terms of social aspects'. Safety (seven retailers) emerged as the principal theme followed by job satisfaction (five) and ease of use (four). Creating communities, specifically using smart-phone apps, was a theme discussed by four retailers. Retailers H and I indicated that having such advanced technologies (as IoT) in place created a pride among staff members.

Figure 1 below summarises the overall findings of how IoT deployment integrates the supply chain processes and ultimately improves the sustainability of retail firms.

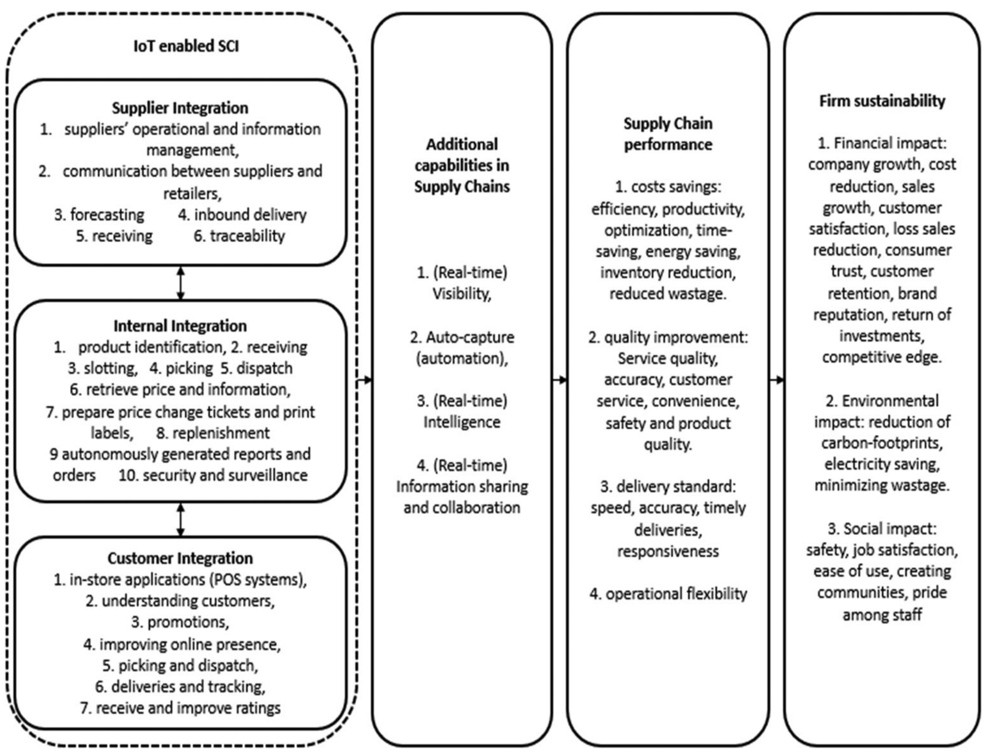

Figure 1. Findings of how IoT enable firm sustainability in Australian retail.

5. Discussion and implications

This exploratory study reveals how the IoT can strengthen supply chain ICT infrastructure to impact SCI and subsequently improve the performance of Australian retail supply chains and firms. Confirming its popularity, all study informants were mindful of the IoT's disruptive effect on SCM. Notably, the study reveals the coexistence of a vast array of primary IoT forms facilitating Australian retail supply chains. The finding corroborates with de Vass et al. (2018)'s empirical study in the same context and Hopkins and Hawking (2018)'s single case study on an Australian transporter. In contrast to the findings of Tu (2018), the widespread diffusion of primary forms of IoT was evident in the Australian retail supply chain context. Popular forms of IoT are location-based telemetry (use of GPS and sensor data together), smart-phones, palm-held devices, sensors, scanners, IP-cameras, security and surveillance devices, and bar-coding systems. While all informants reported the benefits from IoT to integrate their supply chains further, the best value addition was evident when multiple IoT forms are deployed collectively.

Although the scholars suggest for an item-level tagging (Ben-Daya, Hassini, and Bahroun 2017; Hofmann and Rüsch 2017), the RFID is mostly utilised so far at the unit level (i.e. box, pallets, and container). However, digital communication via smart-phones is progressively more exploited. Given that individuals inevitably carry smart-phones, there seems to be a drive to piggy-back on its resources as the central device for customer integration.

This exploratory study further unearths how each SCI dimension is affected by IoT deployment. For instance, IoT data at the retail point, when shared with suppliers, improve their processes to fulfil retailers' inventory needs. Furthermore, the information exchange with suppliers helps in inventory forecasting, timely delivery, receiving, and traceability processes. Similarly, IoT deployment benefits in-house logistics functions such as inventory management, transportation schedule, and customer order fulfilment. Importantly, this study reveals that IoT improves communication among functional silos within the retail firm helping each key person to access the data. Also, IoT, as in-store technology, enhances the customer's shopping experience. For example, the IoT facilitates multiple interactions between customers and products/services. For the online presence of retailers, the IoT can anticipate customer requirements and help to pick and offer delivery schedules all tailored to their specific needs. Retailers further capitalise on data that are captured through IoT technologies to demographically identify customer needs that trigger promotions and shopping suggestions to improve sales. Reliance on the IoT not only helps improve retailers' customer ratings, it also facilitates customers capacity to rate/review retailers' services for improvement. Interviewees suggest that IoT potentially has a more significant role to play in a rating-based economy for retailers to compete in the market.

The findings validate IoT related conceptual discussion, theory, and anecdotal evidence of the plausible benefits of partner integration in literature. Prior studies, for example, includes the proposed distributed architecture of supply chain over the IoT (Ping et al. 2011); proposal for IoT infrastructure for collaborative warehouse management (Reaidy, Gunasekaran, and Spalanzani 2015); a conjoined prototype of IoT and cloud to integrate supply chain processes (Yan et al. 2014) and the empirical study on the impact of IoT on SCI (de Vass et al. 2018). This exploration, however, extends the scope of prior studies to reveal proof-of-concept of IoT use in retail supply chains has improved SCI to have a positive effect on supply chain and firm sustainability.

The findings of this study further reveal that IoT-enabled SCI improves supply chain performance. More specifically, supplier-, internal-, and customer-related processes are integrated and made visible by using IoT-generated data. This enhances the supply chain performance dimensions on cost, quality, delivery, and flexibility. For example, retailers consistently stated that cost was reduced through improved efficiency that IoT offer; quality improvement (e.g. DIFOT) occurs by enhanced services. However, this depends on the retailer-specific initiative, the forms of the IoT in action, and the extent it is integrated into operational processes. These exploratory findings support the argument that IoT deployment enhances supply chain operations (Ben-Daya, Hassini, and

Bahroun 2017; Haddud et al. 2017). It also corroborates the importance of engaging with 'on the ground' narratives from managers, as proposed in the study by de Vass et al. (2018).

This study also qualitatively assessed the IoT deployment for its ability to enhance the retailers' operational capabilities. The findings suggest that the IoT-enabled SCI offers additional capabilities such as data auto-capture (automation), visibility (real-time), intelligence (real-time insights), and improved communications internally and externally with business partners. The findings are significant in the sense that no earlier studies so far have attempted to find what additional capabilities that various forms of the IoT provide. As we embark on the Industry 4.0 era, the IoT is considered one of its founding technologies (Ben-Daya, Hassini, and Bahroun 2017; Hofmann and Rüsch 2017), which offer data auto-capture ability within cyber-physical systems. As retailers are increasingly moving towards the digitalisation of logistics activities, IoT functionalities need to be factored in for more pervasive, reliable, and real-time visibility in the supply chains. As cloud technologies are hosting more and more storage and processing power, big-data analytics, artificial intelligence/machine learning (AI/ML), and Blockchain are making further inroads, where IoT may provide higher intelligence on the flow of goods helping in key decision-making. Also, many novel technologies are being added to the expanding list of IoT forms in the proposed Industry 4.0. Therefore, the findings of this study can provide a basis to understand the capabilities that IoT can offer in future smart supply chains connecting machines over the Internet.

This study furthermore found that IoT-enabled SCI has improved the retailers' sustainable performance measured on economic, environmental, and social outcomes. The findings substantiate the conceptual discussions of IoT adoption that are likely to improve the supply chain sustainability (Borgia 2014; Manavalan and Jayakrishna 2018). For example, IoT-enabled SCM was have improved the retail firms' financial performance by fostering growth, reducing costs, and representing a positive return on investment. Environmental sustainability impact is evidenced primarily due to paperless operations, reduced carbon footprints, reduced energy consumption, waste minimisation, and recycling. Further, the social performance was realised by improved safety and job satisfaction, creating communities, and new job opportunities, which may transform into longstanding value. Moreover, IoT applications free up retailers' time that is allocated more on productive and innovative tasks, and planning activities. While the discussion on circular economy and sustainable supply chain intensifies, these findings on how IoT fits into the Industry 4.0 framework are beneficial (Dev, Shankar, and Qaiser 2020).

5.1. Theoretical implications

This study contributes theoretically to the SCM literature, where the IoT related studies are still emerging. It fills a methodological gap in the literature (Linton 2017) by undertaking an interview-based qualitative investigation of IoT technology applications in the retail context (Abdel-Basset et al. 2019a; 2019b). The literature thus far has focused on conceptualising the impact of IoT technologies in supply chain processes (i.e. source, make, delivery, return), while providing a limited empirical account of its practical application (Ben-Daya, Hassini, and Bahroun 2017). The one exception is the case of a 3PL provider investigated by Hopkins and Hawking (2018), which found that the IoT is being used in the sector to enhance driver safety, lower operating costs, and reduce the environmental impact of vehicle movement. Nevertheless, such findings remain within the in-cabin deployment and have not been interpreted for their potential to improve the logistics processes of customers. Tu (2018), using mixed methods, found perceived benefits, costs, and external pressures to determine the IoT adoption in the supply chain. As supply chain technology adoption is more evident in retail operations across the sectors (Balaji and Roy 2017), the potential benefits of the IoT in managing the retail logistics process remain primarily theoretical, for the retailers those who are increasingly looking for evidence before they move on to adopt advanced forms of IoT (e.g. smartphone, palm-held devices, more sensors at every touchpoint, GPS and surveillance cameras) to track and trace the movement of goods along the retail chain. This study is the first of its kind to reveal the practical application of IoT technologies. This is unique in the sense that this study has established the prospective retailers' confidence in implementing the latest form of IoT technologies based on the experience of the sample respondents discussed in the findings.

From an OC perspective, this study argues that IoT implementation improves the existing ICT infrastructure that offers retailers an ability to integrate their internal and external logistics processes. Thus, the IoT enhances the organisational (retailers) capabilities by improving their ability to collect the data and store and analyse it for better business intelligence (e.g. supplier and customer-related decision). This takes the knowledge a step forward where the IoT brings in additional capability over the legacy ICT ecosystems for real-time data capture allowing the suppliers and customers to make better operational decisions through data integration (Balaji and Roy 2017).

5.2. Practical implications

As technologies progressed, retailers have gradually internalised traditional ICT such as telephone, fax, email, bar codes, RFID, EDI, and ERP to support their logistics functions (Vanpoucke, Vereecke, and Muylle 2017). However, they must be wondering how the emerging IoT can enhance business values. Further, they are constrained and cannot decide on the appropriate technologies because of the limited knowledge and lack of experience in IoT deployment in enterprises (Nabeeh et al. 2019). This study contributes to bridging this gap by providing real-life insights from IoT users among Australian retailers. IoT technology (RFID being the earlier form) is not new in logistics, and the tracking and tracing of goods using ICT (i.e. GPS) have been around for years. However, what is new today is the availability of various forms of IoT technologies with better business value-add. The emerging IoT in the form of sensors, actuators, smart mobile, and near field communicators can facilitate connectivity, security, event monitoring, and advanced analytics for business intelligence. This is benefiting retail logistics operations, suppliers, and customers. Therefore, smart supply chains powered by IoT technologies offer a practical tool for retailers and helps in further proliferation of IoT in this space. This proliferation not only improves sustainability but also captures in-depth information that may help further evaluate the improvement (Abdel-Basset et al. 2019a). With retail being at the forefront of IoT digitalisation (Balaji and Roy 2017), it may lose the competitive edge if adoption decisions are delayed. Further, IoT being massive in its potential and disruptive nature, its functionalities are considered as an extension of the previous ICT. However, the earlier technologies are overly computer-based (e.g. robotics, computer-integrated manufacturing, and design, actuators, and sensors), whereas the IoT technologies, in contrast, are characterised by machine-to-machine communication indicating its presence over Internet-based systems. In this Internet-centric paradigm shift, the retailers can see object-to-object and object-to-human communication where more data can be stored, analysed, and communicated for real-time intelligence. For instance, a fully functional IoT based system prototype can be designed using the design science research (Miah, Gammack, and McKay 2019) as a demonstrative solution case for addressing the Industry 4.0 demands. Therefore, the findings may serve as a piece of concrete evidence and inspire practicing managers, industry associations, and policymakers to speed up spending in IoT adoption decisions and related policy. Ultimately, this technology enhancement may better serve the customer at a lower cost while preserving the environment and up-keeping social aspects.

6. Conclusion

This exploratory study of Australian retail supply chains reveals that IoT implementation improves logistics processes internally within the retail sector and externally with suppliers and customers. This demonstrates the on-the-ground benefits of adoption and integration of IoT technologies and therefore complements and expands on the primarily theoretical benefits identified in the literature thus far. Thematic analysis of semi-structured interviews with retail practitioners shows that the IoT comes with additional capabilities, namely visibility, auto-capture, intelligence, and information sharing. This enables the integration of logistics processes and improves the supply chain performance dynamics on cost, quality, delivery, and flexibility, which also impact the retail firm's sustainability (economic, environmental, and social). The findings may inspire managers, industry associations, and policymakers to understand the importance of IoT-enabled smart supply chains in this Industry 4.0 era.

There are a few limitations that may guide future studies. The case interviews were intended to gather the evidence of IoT benefits and the extent of its capability to integrate the logistics processes. This approach included retailers across sectors, but no single sector had a major representation of retailers. The limitations in the sample size posed an issue of the generalizability of the findings. Therefore, future research needs to include more retailers from each specific sector, having a sample size big enough to carry out intergroup analysis among small, medium, and large retailers. This analysis will offer insights on the IoT implementation where the process integration may vary depending on firm size or the specific sector. Moreover, even though IoT is conceptualised to gain visibility throughout the supply chain (Ben-Daya, Hassini, and Bahroun 2017; Majeed and Rupasinghe 2017), the study is limited to retailers' perspective. Involving the first-tier partners (i.e. supplier, customer) or ideally beyond the first-tier (i.e. grower) vertically, and also 3PL service providers and other horizontal partners may reveal more objective evaluation of sustainability via IoT along the supply chain and demonstrate how the benefits are shared. Given the impact of the IoT in SCM is identified, exploring opportunities and challenges to effective IoT implementation may offer additional insights for future Industry 4.0 proliferation. While the findings unearth very little activity of IoT in reverse logistics, exploring the obstacles and enablers of IoT in closed-loop SCM space is also vital as we pursue a circular economy.

Disclosure statement

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