The "Internet of Things" enabled supply chain integration and performance – A mixed method investigation of the Australian retail industry

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Submitted by

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Abstract

The Internet of Things (IoT) is a next generation of Internet connected devices and sensors embedded within information and communication technology (ICT) systems in a digitally-enabled environment. It supports supply chain process integration by capturing and transferring key information in real-time. Integrating emerging IoT into the current legacy of ICT systems is unique because of its intelligent, autonomous and pervasive applications. While the impact of ICT-enabled supply chain integration (SCI) in improving firm performance is extensively researched, empirical studies on emerging IoT technologies in integrating supply chain processes is limited. It remains overly rhetoric in literature for its inherent benefits. Thus, it raises a question of whether IoT technologies have the capability to integrate supply chain processes and influence the supply chain performance through the power of data capture and exchange. Therefore, drawing on organisational capability theory, this empirical study develops a holistic model to investigate the effect of IoT capabilities on multiple dimensions of supply chain process integration (e.g. suppliers, customers and internal functions), and, its effect on supply chain performance and, ultimately, firm performance.

A mixed methods approach was employed. Cross-sectional survey data from 227 Australian retail firms was analysed using structural equation modeling (SEM), and the results were validated with 13 in-depth interviews with managers from the retail industry. The SEM results reveal that IoT capability is perceived to have a positive influence on internal and external (e.g. customer and supplier) process integration that, in turn, positively affects supply chain and firm performance. Further, IoT-enabled external integration was perceived to influence supply chain performance significantly more than IoT-enabled internal integration. Qualitative analysis supports the quantitative findings above and reveals that IoT capability improves supply chain visibility, auto-capture, intelligence, and information sharing resulting in greater SCI, to influence supply chain performance dimensions of cost, quality, delivery and flexibility, to effect firm's economic, environmental and social criteria.

In terms of theory, this study contributes to SCI and IoT literature by providing an empirical support for IoT-enabled SCI and demonstrating how it helps to integrate the internal and external (supplier and customer) logistics functions that can enhance both supply chain performance and firm performance. The use of organisational capability theory offers a new

perspective on the benefits of emerging IoT capability in achieving SCI in relation to data capture and communication in the supply chain for performance improvement.

Practically, the study provides insight for managers to understand the potential of IoT technologies in the form of supplier and customer integration into a firm's internal logistics functions. The study shows that managers developing IoT-enabled SCI capability can reap the benefits in the supply chain and in firm performance. Higher level of SCI needs the support of newly emerged IoT technologies such as RFID, sensors and smartphone and device applications to capture and transfer data for intelligent and timely decision making. To achieve greater benefits of IoT in an integration context, managers must stretch their focus from isolated organisational management to the entire supply chain perspective.

Declaration

I, Tharaka de Vass Gunawardena, declare that the PhD thesis entitled "*The "Internet of Things" enabled supply chain integration and performance – A mixed method investigation of the Australian retail industry*" is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work".

[redacted]

27/08/2018

Signature **Date**

Publications-Journals and Conferences

Journal Articles

1. de Vass, T., Shee, H., & Miah, S. J. (2018). The effect of “Internet of Things” on supply chain integration and performance: An organisational capability perspective. *Australasian Journal of Information Systems*, 22.

- A-Ranked Journal on Australian Business Dean’s Council Journal Quality list.

Conference Papers

2. de Vass, T., Shee, H., & Miah, S. J. (2018). Internet of Things for improving Supply Chain Performance: A Qualitative study of Australian retailers. Australasian Conference of Information Systems, UTS, Sydney, Australia. 4th December 2018.

3. de Vass, T., Shee, H., & Miah, S. J. (2018). Effect of “Internet of Things” on supply chain digital integration and firms’ sustainability performance. Paper presented at the 16th ANZAM Operations, Supply Chain and Services Management Symposium, CQUniversity, Brisbane, Australia. 4th June 2018.

4. de Vass, T., Shee, H., & Miah, S. J. (2017). “Internet of Things” as creative disruption of supply chain digital integration process: Australian retail industry perspective. Paper presented at the Australian and New Zealand Academy of Management Conference (ANZAM), RMIT University, Melbourne, Australia. 7th December 2017.

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- Awarded Best Paper award in the Stream: Technology, Innovation & Supply Chain Management.

Working papers and manuscripts in preparation

5. de Vass, T., Shee, H., & Miah, S. J. (Working paper). Effect of “Internet of Things” on supply chain integration to impact supply chain and firm performance. To be Submitted to the *Supply Chain Management: An International Journal.*

- Currently working on a paper based on the mixed methods findings of my thesis that was presented at 16th ANZAM Operations Management Symposium.

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To my son Leander, this thesis is dedicated to you.

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List of Abbreviations

ANZSIC	Australian and New Zealand Standard Industrial Classification
ABS	Australian Bureau of Statistics
AGFI	Adjusted Goodness-of-Fit
AVE	Average Variance Extracted
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
EDI	Electronic Data Interchange
EFA	Exploratory Factor Analysis
EM	Expectation Maximisation
ERP	Enterprise Resource Planning
GFI	Goodness-of-Fit Index
ICT	Information and Communication Technology
IoT	Internet of Things
KMO	Kaiser-Meyer-Olkin
MAR	Missing at Random
MCAR	Missing Completely At Random
MI	Multiple Imputation
ML	Maximum Likelihood
MNAR	Missing Not At Random
NFI	Normed Fit Index
PAF	Principal Axis Factoring
RMSEA	Root Mean Square of Approximation
SCI	Supply Chain Integration
SEM	Structural Equation Modeling
SFL	Standardised Factor Loadings
SMC	Squared Multiple Correlation
SRMR	Standardised Root Mean Square Residual
TF	Totally Free
TLI	Tucker-Lewis Index
$\mathbf{x^2}$	Chi-Square

Chapter 1
Introduction

1.1 Introduction

This chapter lays the foundation for the dissertation by introducing the study objectives and the research questions. By outlining the significance of Supply Chain Integration (SCI) in improving supply chain performance, it explores the potential positive effects of one of the most theoretically formidable emerging forms of ICT, the Internet of Things (IoT) to strengthen SCI in the Australian retail industry. This chapter explores the scarcity of empirical evidence on the effect of IoT as a digital enabler for SCI, despite the abundance of ICT research on SCI. The chapter makes the argument that this study is necessary and relevant in light of this gap in the literature, as well as introducing the methods used to investigate the perceived effect of IoT on SCI to improve supply chain performance, in turn impacting firm performance, from the Australian retail industry perspective.

Section 1.2 of this chapter establishes the background context of the research problem, identifying the relationship between IoT capability and SCI to impact on performance and highlighting the gap in the literature, before positioning the research questions in section 1.3. It also briefly introduces the research context, the Australia retail industry, in section 1.4 and justifies its selection. Subsequently, section 1.5 moves onto a discussion of the research methodology, then ethical consideration (section 1.6), followed by the significance and the contribution of the study (section 1.7). Finally, the introductory chapter concludes after outlining the subsequent chapters (section 1.8) of this dissertation.

1.2 Research motivation

In the current dynamic and competitive business environment, supply chains compete against one another on behalf of their focal firms (Christopher 2016; Christopher & Towill 2001). In a scenario of network-based competition, the effective and efficient flow of goods and services determine the strength of a supply chain (Rai, Patnayakuni & Seth 2006). Within this context, the notion of internal and external integration emerge as a key enabler of improving supply chain performance (Alfalla-Luque, Medina-Lopez & Dey 2013; Ataseven & Nair 2017). Supply chain integration (SCI) is defined as collaborative inter- and intra-firm management on the operational, strategic, and tactical business processes to achieve the efficient (lowest cost at greatest speed) flow of products, information and finance, to ultimately provide the maximum value to the customer (Alfalla-Luque et al. 2013; Huo 2012; Yu 2015; Zhao et al. 2011). That includes both internal and external (supplier and customer) integration across the entire supply chain through collaborative communication and information sharing (Alfalla-Luque et al. 2013). The relentless pursuit of competitive edge has made supply chain integration a central theme of supply chain research, widely considered from strategic perspectives (Ataseven & Nair 2017; Maleki & Cruz-Machado 2013).

ICT has traditionally been, and continues to be, an essential digital enabler of SCI in a supply chain (e.g. EDI, ERP), by facilitating internal and external information flow between supply chain partners (Kim 2017; Rai et al. 2006; Vanpoucke, Vereecke & Muylle 2017). Consequently, a multitude of studies (Kim 2017; Li et al. 2009; Rai et al. 2006) exploring SCI as a single construct confirm the effect of ICT on SCI. However, Flynn, Huo and Zhao (2010) argue that researching supply chain integration as a unidimensional construct may obscure vital contributions, or even result in false conclusions. They thus rationalise the conceptualisation of supply chain integration as a *multidimensional* construct. Consequently, Yu (2015) finds a positive effect of ICT on three supply chain integration dimensions (internal, supplier and customer).

However, the limitations of traditional Internet-based ICT have paved the way for new services and applications such as the Internet of Things (IoT) that leverage the interconnection of physical things with digital world (Atzori, Iera & Morabito 2010; Constantinides, Kahlert & de Vries 2017; Mattern & Floerkemeier 2010). Firm drive for efficient internal operations, coupled with collaboration with suppliers and customers, has driven digital transformation (Ben-Daya, Hassini & Bahroun 2017; SDA National 2018). Envisaged as a leading enabler of the approaching Industry 4.0 era of automation and logistic digitalisation (Hofmann & Rüsch 2017; Trappey et al. 2017), it is argued that the emerging IoT technologies could potentially revolutionise supply chain management (Ben-Daya et al. 2017; Tu 2018). Although the literature abounds with the ways ICT integrates the supply chain processes to improving performance (Li et al. 2009; Qrunfleh & Tarafdar 2014; Rai et al. 2006; Vanpoucke et al. 2017), none of these studies have considered the effect of emerging disruptive technology innovations such as IoT within this context. Despite IoT being reported to strengthen SCI (Ping et al. 2011; Tu 2018; Wu et al. 2012), no study has emperically assessed the effect of emerging IoT on SCI. Thus, empirical investigation of IoT capability for such process integration needs further attention (Ping et al. 2011; Yan et al. 2014).

Representing an advancement in technological innovation of connecting objects and devices through the Internet, IoT is defined as a global platform of Internet connected smart objects that allows people and things to connect anytime, anywhere using any network or services (Atzori et al. 2010; Borgia 2014; Vermesan et al. 2011). This network of objects (e.g. devices, vehicles, machines, containers) embedded with sensors and softwares has the potential to collect and communicate data (Edwards & Hopkins 2018). Thus, IoT can affect day to day life by sharing information among individuals, organisations, industries, environment and society (Borgia 2014). This progression of ICT (e.g. computers, ERP, email, fax, phone, and WMS) presents applications with the ability to capture and share data in real-time in a network of organisations (Borgia 2014). This "digital upgrading" of conventional objects via Internet connectivity generates additional functionality (Mattern & Floerkemeier 2010). Therefore, IoT capabilities differ from previous ICT capabilities due to their ubiquity, intelligence and autonomy (Constantinides et al. 2017).

Conventional ICT technologies help monitor supply chain functions such as transportation, storage, distribution, purchasing, sales and returns (Vanpoucke et al. 2017). With many other smart devices recently joining the list under the newly coined IoT umbrella of technologies, the potential to address information capture and exchange in real time has multiplied (Atzori et al. 2010; Borgia 2014). Real-time monitoring is a reported capability outcome of the pervasive presence of RFID tags, sensors, actuators, smart devices, machines and smartphones. Monitoring and information exchange can extend to almost every node in global supply chain processes (Atzori et al. 2010; Haddud et al. 2017). Hence, as a unique capability, IoT has the potential to address the information gap by capturing additional data flowing among supply chain entities, processes, equipment and people, transfer, process and action in real-time (Ben-Daya et al. 2017; Borgia 2014; DHL 2015).

In this study, IoT in supply chain operarationalisation context is defined as an autonomous Internet connected platform of ubiquitous smart objects that can help in seamless integration of in-depth real-time data of inter- and intra-firm supply chain processes to facilitate the exchange of goods and services, while enhancing performance of global supply chains and its partner firms (Ben-Daya et al. 2017; Constantinides et al. 2017; de Vass, Shee & Miah 2018; Dweekat & Park 2016; Haddud et al. 2017; Liu & Sun 2011a; Majeed & Rupasinghe 2017). As a result, IoT is reported to be a conduit across the divide between physical and digital world by synchronising the information flow with the physical flow of goods (Ping et al. 2011). Although the literature identifies the recent emergence of IoT as an effective approach for integration via data capture and sharing, further research is recommended to investigate its ground reality (Verdouw et al. 2016; Yan et al. 2014). Moreover, the literature to date on IoT supply chain applications is broadly rhetorical and particularly prescriptive in performance improvement (Ben-Daya et al. 2017; Mishra et al. 2016).

Research on IoT is still emerging (Liu & Gao 2014), and its management and operations potential has seldom been explored (Whitmore, Agarwal & Da Xu 2014). Linton (2017) reports that overall, out of 2.5 million articles published on ICT to date, there are just 20,670 available on emerging technologies and only 67 academic journal articles that discuss emerging technology and supply chain interdisciplinary. Literature on the use of IoT in supply chain application is restricted to model building (de Rivera et al. 2014; Liu, Zhao & Li 2015; Liu 2015; Liu & Gao 2014; Majeed & Rupasinghe 2017; Pang et al. 2012; Qin, Wang & Li 2015; Thoma et al. 2013; Vargheese & Dahir 2014), conceptualisations (Gong & Tian 2012; Lianguang 2014; Magerkurth, Haller & Hagedorn 2010; Ng et al. 2015; Ruan, Wu & Wu 2012; Sánchez-Picot et al. 2014; Zhang 2014; Zhou, Chong & Ngai 2015b), and simulations (Chen 2015; Juntao, Xiaolin & Gang 2013; Musa et al. 2014). Despite positive conceptualisations and the conspicuous presence of IoT in supply chains, there is no sufficient empirical evidance of IoT deployment and the way it affects supply chain or firm performance (Ben-Daya et al. 2017; Mishra et al. 2016). Therefore, IoT capabilities in collecting and transmission of data for improved supply chain or firm performance remain unexplored (Ben-Daya et al. 2017; Mishra et al. 2016; Verdouw et al. 2016). In particular, whether IoT-enabled SCI can affect the performance. Therefore, this study sets out to examine the effect of IoT capability on SCI to improve supply chain and firm performance in the Australian retail industry.

Strengthening SCI is critical in retail supply chain (Charaton 1999). Retailing is 'the set of business activities that adds value to the products and services sold to consumers for their personal or family use' (Levy, Weitz & Grewal 2012). Retail firms face various challenges due to the dynamic nature of global reach and product portfolios in the retail world and unpredictable customer demand (Majeed & Rupasinghe 2017). Moreover, retail supply chains are demand driven (van der Vorst et al. 2016). Therefore, intense digital connectivity and coordination within the supply chain partners via emerging technology is vital (Fleisch & Tellkamp 2005). The IoT platform connects smart objects and users to provide many innovative approaches for retailers serving their customers (Constantinides et al. 2017). Hence, IoT may play a significant role in the retail industry, managing supply networks in response to customer demands (Yu et al. 2015). There are rapidly evolving consumers' buying behaviour, with digital devices such as smartphones and tablets inspiring consumers to search and shop online, anytime, anywhere, irrespective of geographical boundaries. Therefore, the retail industry is at the forefront of embracing IoT to create value via ease of use, superior functionality, aesthetic appeal and presence. It offers opportunities in information exchange, revenue management, and overall customer experience (Balaji & Roy 2017).

Organisational capability theory underpins this research. IoT adoption can be viewed as an additional capability appended to the current ICT capability of an organisation. This study uses IoT capability as a progression of ICT capability (Borgia 2014) to facilitate intra- and inter-firm communication and information flow in more integrated way. Therefore, from an organisational capability theory perspective, IoT enhances the ability to integrate supplier, customer and intra-firm logistics processes. Intra- and inter-firm information sharing (Huh, Yook & Kim 2008), inter-firm relationships (Lorenzoni & Lipparini 1999), and communication (Huh et al. 2008; Kusunoki, Nonaka & Nagata 1998) represent process integration capabilites. Therefore, organisations can build additional capabilities by adopting IoT into the mainstream business based on the legacy of ICT. Inter- and intra-firm communication and information exchange are perceived to be facilitated by IoT. The organisational capability perspective suggests that a firm must develop its own resources and capabilities for performance improvement (Huo 2012; Rai et al. 2006). Notably, integration is a higher order process capability that can directly influence firm performance (Huo 2012; Verona 1999). ICT therefore cannot have a direct effect on performance; rather it needs to be blended with other organisational resources (e.g. human and financial resources) for performance improvement (Bharadwaj 2000; Rai et al. 2006). Likewise, IoT can be seen as improving the overall integration ability of an organisation. Therefore, in this study, IoT capability is defined as additional features of pervasiveness, identification, sensing, automation, intelligence and communication capabilities via the IoT platform to strengthen the supply chain process integration with the purpose of improving firm performance (Ben-Daya et al. 2017; Constantinides et al. 2017; de Vass et al. 2018; Mishra et al. 2016; Whitmore et al. 2014).

Examining the role of IoT in supply chain is important (Ben-Daya et al. 2017; Li & Li 2017) as it continues to grow significantly in firms' ICT strategy and has broad applications (Atzori et al. 2010; Borgia 2014). Of the 593 global firms surveyed in 2014, 80% agreed that IoT solutions were the most strategic technology innovation for their organisation in the past decade; 65% firms, of which 70% are in the Asia-Pacific, have deployed or are in the process of implementing IoT solutions (Forrester Consulting 2014). Surprisingly, the existing literature provides very little guidance for practitioners to support the adoption of an emerging technology, to transform from having a fragmented supply chain to the final consumer being served by an extremely efficient and effective supply chain (Linton 2017). The advances in IoT applications in the form of sensors were expected to revolutionise retail sector (Kahlert, Constantinides & de Vries 2017), but their acceptance and potential in supply chain integration has been investigated in a limited way. As Lee (2017, p. 1) posits that IoT usability is currently conceptualised with limited analytical and empirical evidence.

1.3 Research questions and aims

The two objectives of this research are to:

1. Empirically investigate the hierarchical (sequential) effect of IoT on the three dimensions of supply chain integration processes (suppliers, internal and customers) that can enhance the performance of the supply chain and in turn firm performance.

   The sub-objectives are to:

   (i) investigate the effect of IoT capability on supplier integration;

   (ii) investigate the effect of IoT capability on internal integration;

   (iii) investigate the effect of IoT capability on customer integration and

   (iv) investigate the effect of the three dimensions of IoT-enabled SCI on supply chain performance.

   (v) investigate the effect of IoT-enabled supply chain performance on firm performance.

2. Explore the ground reality of IoT applications prevalent in Australian retail supply chains, and how the SCI has affected their supply chain and firm performance.

   The sub-objectives are to:

   (i) uncover the extent IoT help in supplier process integration;

   (ii) uncover the extent IoT help in customer process integration;

   (iii) uncover the extent IoT help in internal integration, and

   (iv) uncover the extent it helps in performance improvement of supply chain firms.

Therefore, the following two research questions guide the respective objectives of the study:

Q1. Can IoT-enabled SCI influence supply chain performance and subsequently improve firm performance?

Q2. What extent the existing IoT deployment effects SCI and in turn influences supply chain and firm performance?

1.4 The Australian retail industry and IoT

The retail industry is a critical part of the Australian economy and changes within and to it will impact on all Australians individually and Australia as a whole (SDA National 2018). However, retailers are currently going through many challenges due to intense competition, increased internationalisation and technological advancements. Therefore, they are seeking ways to rapidly transform the way they do business to survive and thrive (Wallström et al. 2017).

Retailing is also defined as '…the set of activities that markets goods or services to the final consumers for their personal or household use' (Singh et al. 2011, p. 159). The Australian and New Zealand Standard Industrial Classification (ANZSIC) defines retail as purchase and sell of goods to the general public without any significant transformation (ABS_ANZSIC 2013). Retail supply chains are extremely complex (Popli, Madan & Jaiswal 2013), with both customer service and cost efficiencies as prerequisites in the competitive retail landscape (Hübner, Kuhn & Sternbeck 2013), where only the fittest will survive (Balazs & Zinkhan 2003).

Although Australia's retail industry employs more than 1.2 million (SDA National 2018), accounting for 10.7% of total Australian employment (Productivity Commission 2011), the growth of both employment and wages are restrained and unable to match up with other industries (Delloitte Retail Report 2017). As early beneficiaries of ICT benefits, emerging ICT applications have historically played a major role in Australia's productivity growth, with the retail industry being a top beneficiary (Bureau of Communications Research 2016). However, currently, Australian firms are not at the forefront in technology adoptions, ranking in the middle among advanced economies, highlighting the need for further digital maturity to improve the Australia's trailing productivity (Department of Industry Innovation and Science 2016).

Over recent years, there has been massive changes in the structure and organisation of Australian retailing, with digital revolution being a key driver (SDA National 2018). Both Australian retailers and the customers believe that IoT can have a major impact in the Australian retail industry and are keen to capitalise on its benefits (Deloitte Digital Retail 2015; Zebra 2015). The Australian businesses that are not capitalising on its full potential could miss out on productivity benefits (Department of Industry Innovation and Science 2016). Furthermore, policy makers need valid evidence to drive digitalisation efforts. IoT is a large part of the potential digital transformation, but, due to IoT's sophistication and pervasiveness, conventional measurements find it difficult to specifically identify its effect on productivity; therefore, stronger evidence on the relationship between IoT and its performance outcomes is warranted (Bureau of Communications Research 2016; Department of Industry Innovation and Science 2016). What the status of IoT in Australian retail supply chains is, whether IoT can help in supply chain and logistics process via its data capture and transmission and whether the focal firm and its suppliers and customers are benefited from this deployment are yet to be clarified. Given this backdrop, it is important to examine the effect of IoT on retail supply chains and the way it affects performance.

1.5 Research methodology

This research has adopted a mixed methods approach. As each research method has its potential weaknesses in itself, mixed methods were adopted to complement the shortcomings of each one and to understand a complex research problem. Hence, the study was conducted in two phases: survey and interview (Flint, Golicic & Davis 2012). The latter was used to validate, interpret and support the results obtained from the survey method. Most research on IoT adoption employs just a single method of research (Tu 2018). Although a single-method approach might not be adequate to describe the role of IoT across complex multitude of supply chain processes, the existing literature has not widely adopted a mixed method research approach (Tu 2018). ICT research communities wish for methodological diversity, but only a few ICT studies have employed mixed methods (Venkatesh, Brown & Bala 2013). Equally, mixed methods are rarely used in supply chain management research, which is dominanated by quantitative studies (Flint et al. 2012; Golicic & Davis 2012). Therefore, as Tu (2016) points out, there is an opportunity to advance this interdisciplinary phenomenon by applying mixed methods, which offer greater breadth and depth to better understand how IoT capability can affect supply chain operations and overall firm performance.

Following ethics approval, primary data was collected in two phases. In Phase 1, a survey was employed for data collection. The survey instrument was adapted from established literature except for newly developed IoT capability measures. The instrument was pre-tested through a pilot study prior to the launch of the main survey. The final version of the survey was distributed online among potential respondents representing the Australian retail industry. The unit of analysis was a retail firm, though the respondent from each firm in the sampling frame was mostly supply chain or IT managers with adequate knowledge of supply chain management. The survey returned 227 responses, which represents a response rate of 41%. The descriptive statistics was analysed using SPSS 23 followed by structural equation modeling (SEM) using SPSS AMOS 23. This two-step procedure of the SEM method was performed (Anderson and Gerbing (1988). SEM helps establish the measurement model along with assessment of construct reliability and validity followed by analysis of the structural path model to test the proposed study hypotheses.

Phase 2 involved qualitative data collection via semi-structured interviews with 13 managers that represented 12 retail organisations and a third-party logistics (3PL) service provider. The rational for the inclusion of a 3PL is that most of the retail respondents voiced the 3PLs key role in their supply chains fulfilling logistics delivery, and they are at the forefront of IoT adoption in logistics movement. So, a manager from a 3PL service provider was also interviewed to collect evidence of IoT applications and how that benefits supply chains. The participating managers reported that they had knowledge in supply chain management and ICT applications across functionalities. The interviews used a semi-structured interview guide which was pre-tested by pilot study for its content validity. The interviews were transcribed and analysed using an open- coding process in Nvivo 11 to identify themes and their relationships (Strauss 1987).

1.6 Ethical considerations

Since both Phase 1 and Phase 2 involved participants who are employees of retail organisations, ethics approval was obtained for this research project from the Victoria University Human Research Ethics Committee (VUHREC). The study was deemed to meet the National Statement on Ethical Conduct in Human Research (2007). The approval was granted from 26/07/2016 for two years, under the application ID: HRE16-169 (Appendix A).

The research posed a low risk to participants. This assessment was made by reviewing the psychological, social, legal, financial, physical and community risks to participants. Professional harm to informants (and their organisations) were minimised by offering stringent confidentiality and anonymity conditions. The first step was to inform all research participants about the research, and potential benefits and related risks. All individuals were advised to gain consent from their managers. Informed consent was therefore elicited, and informants were given the option to end their participation at any point of the process. Confidentiality was safeguarded. In the interviews, the organisations are referred to using a pseudonym, and interviewees' names are changed to protect anonymity, maintain confidentiality and prevent harm. The participants' information documents with an invitation to participate sent for participant recruitment are attached as Appendix B and C. A summary report of the study results was forwarded to those who provided their email addresses.

1.7 Significance of the study

This research contributes to the supply chain management literature, both theoretically and practically. In terms of theoretical contribution, underpinned by the organisational capability theorotical perspective, the study

1. empirically validates the positive effect of IoT capability on the three dimensions of SCI, to improve supply chain performance, and in turn, firm performance, by testing a conceptual framework inclusive of IoT.
2. provides detailed evidence of how various IoT technologies in Australian retail supply chains enable SCI, and influence on supply chain and firm performance.
3. extends organisational capability theory by deploying IoT technologies to enhance firm capability helping to achieve higher order integration capability for performance improvement.

Also, this research has implications for practitioners, policy makers and industry associations. The study

1. provides insights for practitioners that IoT technologies enable information capture that can be a likely help in fact-driven decision making.
2. suggests investment in IoT technologies is a strategic move for better integration of supply chain partners for inventory status, shipment information and market demand. Not investing in IoTs will lead to a loss of competitive advantage.
3. provides evidence of the relationship between IoT-enabled SCI and performance. From organisational capability perspective, the practitioners can therefore support strategies to map the way forward in IoT deployment that can enhance the digital capability.

1.8 Thesis structure

This dissertation is structured into eight chapters.

Chapter 2 reviews the background literature and the theory. The literature on firm performance, supply chain performance, SCI, ICT and IoT was reviewed, while distinguishing the relationship between each, to establish the knowledge gap that was addressed in this research. Organisational capability theory was introduced to explain the study relationships, followed by a discussion of the research context.

Chapter 3 presents the conceptual framework and hypotheses. It rationalises the conceptual framework with each of the nine hypotheses explained.

Chapter 4 discusses the methodology. It provides a comprehensive description of the two phases employed under the mixed methods research approach and reflects on each step, including the instrument development, data collection and methods of analysis.

Chapter 5 reports the findings of the phase one of the study, the quantitative analysis, in relation to the research question one. Opening with the demographic data of the survey sample, it moves on to the preliminary analyses where the data screening and purification process took place. Then, it lays out the results in validation of the conceptual framework and the hypothesis using structural equation modeling (SEM) to report the findings of Phase 1 of the study.

Chapter 6 presents the findings of Phase 2, the qualitative study, according to the themes identified in relation to the research question two and the conceptual framework.

Chapter 7 presents an analysis of the study findings from both quantitative and qualitative phases. It informs the theoretical and practical implications which are discussed in detail.

Chapter 8 concludes the study by bringing together and summarising what was discussed in the earlier chapters. Finally, the chapter concludes with an outline of the limitations of the study and recommends directions for future research.

1.9 Chapter summary

This chapter introduced the study and define the research background, question, objectives, methodology, and the significance of the study. It also presented the details of the study context, the Australian retail industry. Finally, it summarises each chapter in the dissertation. The chapter presented the rationale for examining the relationship between IoT and SCI to improve performance. It was asserted that, due to internal and external pressures, supply chains are increasingly required to be more efficient and effective in execution in order to, in turn, improve the competitiveness of firms. Consequently, SCI is a key concept that emerged to improve the performance of the supply chain. Within this context, ICT is considered a crucial digital enabler for SCI via its ability to facilitate information flow. Although the recent emergence of IoT as a next generation ICT has demonstrated its potential to further synchronise information and physical flows for greater integration, there a gap in scholarship on IoT's effect on SCI or its performance outcomes on supply chains and firms. This study adopts the organisational capability theory perspective to examine the effect of IoT on SCI for performance improvement.

The next chapter reviews the background literature to the study to highlight the identified research gap, and to present the foundation for the conceptual framework used in this thesis.

Chapter 2
The Background and Literature Review

2.1 Introduction

Chapter 1 outlined the study objectives as well as the research questions. It highlighted the implications of SCI and emphasised the role of technologies, in this case IoT, in supply chain operations in enhancing firm performance. This chapter reviews existing research at the intersection of supply chain integration and ICT to explore the potential benefits of IoT for improving SCI and performance. The review reveals the lack of empirical evidence for IoT as an enabler for SCI, and, in turn, supply chain and firm performance.

This chapter commences by reviewing the supply chain management literature and its importance to firm performance in section 2.2. It highlights the importance of supply chain performance in the current context where firms compete against each other through their supply chains. Section 2.3 draws on the supply chain management literature that emphasises the relevance of the SCI concept for improved performance to address volatile market challenges. It reviews research that considers ICT to be a digital enabler for SCI and clarifies its effect in section 2.4. In Section 2.5, IoT literature is analysed to explain what IoT is and to distinguish its extended capabilities from traditional ICT. The literature on the application of IoT in supply chain management context is then scrutinised, highlighting the lack of empirical evidence on the theme in section 2.6. Each section provides academic definitions and explains the characteristics and contribution of each of the different literatures. In section 2.7, the chapter then discusses the gaps in the nascent scholarly body of knowledge on IoT and SCI to highlight the lack of empirical evidence verifying the value created by IoT to complement traditional ICT for digitally-enabled SCI. Section 2.8 then emphasises how organisational capability theory helps us to understand the potential relationship between IoT, SCI and performance. Finally, the chapter discusses the study context, the Australian retail industry and information published on its IoT application in section 2.9.

2.2 Supply chain performance and firm performance

Supply chain consists of ' a set of entities directly involved in the supply and distribution of goods and services, finances and information from a source to a destination (customer).' (Mentzer et al. 2001). To achieve a common goal in the the fulfilment processes (Cagnazzo, Taticchi & Brun 2010; MacCarthy et al. 2016), discrete suppliers, manufacturers, warehouses, transporters, retailers, third party contributors and customers communicate, coordinate and collaborate together by extending their relationships (Stock & Boyer 2009). In this process, they unite as the supply chain (Kristal, Huang & Roth 2010; MacCarthy et al. 2016). Therefore, in a supply chain operation, organisations integrate and jointly manage processes with other organisations in the supply chain, along with various functional areas within the focal organisation (Christopher 2016; Lee, Kwon & Severance 2007; MacCarthy et al. 2016). Supply chain activities include raw material handling, manufacturing, procurement, inventory management and warehousing, distribution, transportation and freight forwarding. It also includes retail to deliver the end product to the customer (Simchi-Levi, Kaminsky & Simchi-Levi 2008).

In a global, competitive business environment, individual establishments need to act as collective members of the broader network of multiple firms and respective supply chain relationships (Christopher 2016; Lambert & Cooper 2000). Supply chains are lengthy and complex operations, that may encompass multiple locations around the world (Marucheck et al. 2011; Wu et al. 2016), as they attempt to meet escalating customer demands, such as customisation, service and price levels (Christopher 2016). This intense competition causes further challenges in getting products to the right place, at the right time, at the lowest cost, and has made firms realise that improving their own operations alone is not adequate. Instead, their entire supply chain needs to be competitive (Li et al. 2006; Van Breedam 2016). Therefore, competition is between the supply chains rather than individual firms (Christopher 2016; Christopher & Towill 2001). Hence, supply chain management performance has become a prerequisite for a firm's sustainable competitive edge (Martínez-Jurado & Moyano-Fuentes 2014; Seuring & Müller 2008; Spekman, Kamauff Jr & Myhr 1998).

The term 'supply chain management' emerged as globalisation began to emerge in the 1980s (Oliver & Webber 1982), as a philosophy for managing a network of firms in a supply chain (MacCarthy et al. 2016; Min & Mentzer 2004). The objective of supply chain management is to manage trade-offs between supply chain partners rather than maximising the individual interests of organisations (Chan & Chan 2010; Oliver & Webber 1982). Consequently, improving firm performance through supply chain management is of significant interest for academics, consultants and business managers alike (Choon Tan, Lyman & Wisner 2002; Christopher 2016; Christopher & Ryals 1999; Simchi-Levi et al. 2008). Supply chain management is defined as 'the management of a network of relationships within a firm and between interdependent organisations and business units consisting of material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finances and information from the original producer to final customer with the benefits of adding value, maximizing profitability through efficiencies, and achieving customer satisfaction' (Stock & Boyer 2009, p. 706). It encompasses the internal management of logistics processes as well as the upstream and downstream interactions between suppliers and customers that support the flow of goods and correlated information (Christopher & Ryals 1999; Prajogo et al. 2016). In a supply chain context, 'logistics' is the management of materials in motion and at rest (Coyle et al. 2008). The reverse flow of products, such as product returns at the end of the lifecycle, product recalls or returned for repair. also merges with the supply chain management concept to create reverse logistics and closed-loop supply chains (Masoumik et al. 2014).

It is well grounded in the literature that supply chain performance positively effects firm performance (Christopher & Ryals 1999; Simchi-Levi et al. 2008). While supply chain strategy yields performance by focussing on cost, quality, delivery and flexibility improvement (Gunasekaran, Patel & McGaughey 2004), it attempts to align with the firm objectives of improving triple bottom line performance to generate environmental, social, and economic benefits (Carter & Rogers 2008; Elkington 1997). Many studies (Lenny Koh et al. 2007; Li et al. 2006; Wisner 2003) have confirmed the positive effect of supply chain management performance on various aspects of firm performance.

The global expansion of supply chain networks and fluctuating market conditions makes managing supply chains to achieve improved performance a complex task (MacCarthy et al. 2016). While effiency in cost and speed remains the fundamental underlying objective for supply chain managers, increasing supply chain complexity, associated costs, and uncertainty means that supply chains must become more responsive to effectively deal with these challenges (Wu et al. 2016). Within this context, SCI has emerged as a key concept to help improve supply chain performance (Ataseven & Nair 2017; Christopher & Towill 2001; Kamal & Irani 2014).

2.3 Supply chain integration and supply chain performance

The primary focus of supply chain management is on integrating business processes among and within supply chain entities. A 'business process' is an array of cogently linked tasks executed with the goal of meeting a defined business outcome (Davenport & Short 1990).

Participants coordinate to control their supply chain processes at strategic, tactical and operational levels, with the objective of improving the value delivered to the final customer (Verdouw, Beulens & van der Vorst 2013). The importance of SCI is largely unquestioned (Vanpoucke et al. 2017), and is found to have a significant impact on supply chain performance (Prajogo & Olhager 2012).

SCI has emerged as a leading research theme in operations and supply chain management literature (Ataseven & Nair 2017; Childerhouse & Towill 2011). Integration is a fundamental element in conceptualising supply chain management (Cooper, Lambert & Pagh 1997; Ellram & Cooper 1993; Ho, Au & Newton 2002; Simchi-Levi et al. 2008) to theorise that the optimisation of the entire supply chain delivers superior performance to a chain of optimised sub-systems (Childerhouse & Towill 2011). Many authors have emphasised integration in their very definition of supply chain management to acknowledge its pivotal validity (Alfalla-Luque et al. 2013; Näslund & Hulthen 2012).

Integration is defined as spanning numerous tangible and intangible elements of a firm's internal and external operations aimed at cultivating efficiencies in their supply chains (Chen, Daugherty & Roath 2009). Many authors have provided specific definitions of SCI. Romano (2003) defines it as a mechanism to assist business processes throughout supply networks by overcoming internal and external boundaries. Accordingly, SCI seeks to collapse boundaries between discrete organisations and inter-firm functions (Ataseven & Nair 2017). Focusing of different forms of decision making (strategic, tactical and operational), Bagchi et al. (2005) define it as far-reaching collaboration among supply network members. Integrating multiple views, Alfalla-Luque et al. (2013, p. 801) define SCI as 'collaborative inter- and intra-firm management on the strategic, tactical and operational levels of activities (and their corresponding materials, funds and information flows) that, starting with raw materials suppliers, add value to the product to satisfy the needs of the final customer at the lowest cost and the greatest speed'.

SCI is a theory (Danese & Romano 2011; Romano 2003, p. 122) that examines how efficiency and effectiveness across the supply chain members can be achieved (Lambert, Cooper & Pagh 1998). Conceptually, the goal of integration is to achieve cost efficiency and deilvery effectiveness across the entire supply chain, while creating value for the customer (Näslund & Hulthen 2012). By streamlining processes and coordinating activities internally, up-stream suppliers and down-stream customers, integration enables organisations to achieve a competitive advantage (Childerhouse & Towill 2011). Childerhouse and Towill (2011); Frohlich and Westbrook (2001); Schoenherr and Swink (2012) 'arcs of integration' publications advances integration theory by examining how SCI significantly correlates with increased performance. Therefore, in conceptualising supply chain management (Christopher, Crum & Holweg 2011; Ellram & Cooper 1993; Ho et al. 2002), SCI represents a mechanism for improving supply chain performance (Alfalla-Luque et al. 2013; Ataseven & Nair 2017).

Integration can also be regarded as the digital connection of business processes within the organisation and across the supply chain (Ataseven & Nair 2017). Consequently, internal integration can positively influence external integration (Huo 2012; Yu et al. 2013). Therefore, business processes should be streamlined and interconnected both inside and outside firm boundaries (Cagliano, Caniato & Spina 2006; Caputo, Fiorentino & Garzella 2018). Given that a typical supply chain consists of material and information flows, integration demands the coordination of the internal, upstream and downstream flow of materials and information (Alfalla-Luque et al. 2013; Frohlich & Westbrook 2001). Thus, the integration of information, physical, and financial flows between supply chain partners is a key attribute (Kukovič et al. 2014; Rai et al. 2006). This interconnection improves visibility, traceability, interoperability and collaborative decision-making within a supply chain (Reaidy, Gunasekaran & Spalanzani 2015). Based on this shared information and coordination via integration, varied decisions and trade-offs can be reached to manifest simplified material flow as the key outcome (Childerhouse & Towill 2011).

There is body of rich empirical research examining the relationship between SCI and performance (Mackelprang et al. 2014). Even though the measured performance aspects are dissimilar and inconsistent, most literature aligns with the claim that SCI results in supply chain performance (Alfalla-Luque et al. 2013; Childerhouse & Towill 2011). For example, Bowersox, Closs and Cooper (2002) argue that integration improves competitiveness via three types of value creation: expanding the extent of economies of scale to reduce waste and costs; increasing market value by offering a convenient product range to the customer and; offering customised products for specific needs. Integration has been found to minimise or eliminate the 'bullwhip effect' of demand volatility, distortion, and amplification created upstream along the supply chain (Danese & Romano 2011; Defee et al. 2010). The recent meta-analyses of the integration literature by Ataseven and Nair (2017); Chang et al. (2016) also agree. Organisational capability theory considers integration as a higher-order capability that can stimulate performance directly (Huo 2012; Rai et al. 2006). However, the performance outcomes are deemed to be contingent upon varied environmental conditions (Wong, Cheng & Lai 2011a).

Although certain authors have examined SCI as a single construct, given the complexity of the concept the multi-dimensional approach has been the preferred alternative in the literature (Alfalla-Luque et al. 2013). The framework by Huo (2012) divides SCI into the two elements: internal integration and external integration. External integration is further divided into the categories of supplier integration and customer integration. Combined, these integrative capabilities directly or indirectly contribute to firm performance (Huo 2012, p. 597). Consequently, many scholars consider SCI as having three dimensions: internal process integration, upstream supplier integration and downstream customer integration (Alfalla-Luque et al. 2013; Ataseven & Nair 2017; Näslund & Hulthen 2012). Internal integration refers to the breakdown of cross-functional barriers within an organisation via synchronised processes by facilitating real-time information sharing across business functions, coordination and strategic collaboration to achieve superior performance (Yu 2015; Zhao et al. 2011). Supplier and customer integration refer to mutual planning, collaboration and strategic information sharing between the focal organisation and its suppliers and customers in managing cohesive processes (Huo 2012; Yu 2015). The operational nature of the each three dynamics varies as per the firm operation. Generally, upstream operations use economy of scale lean strategies up to the decoupling point,[1] while agile strategies becomes important in downstream context when responding to customers (Ciccullo et al. 2017; Towill & Christopher 2002). Therefore, Flynn et al. (2010) argue that researching SCI as a unidimensional construct may obscure vital contributions or even result in false conclusions. They thus argue that SCI be conceptualised as a multi-dimensional construct.

Scholars argue that intra-firm integration is the foundation for broader integration across the supply chain (Schoenherr & Swink 2012; Simchi-Levi et al. 2008). Stevens (1989); Stevens and Johnson (2016) articulate that achieving integration requires several defined stages, starting from cross-functional silos (process integration), moving to full internal integration with seamless flow within internal supply chain, and ultimately to external integration to include suppliers and customers. Several studies demonstrate that internal integration significantly influences supplier and customer external integration (Ralston et al. 2015; Schoenherr & Swink 2012; Yu et al. 2013; Zhao et al. 2011). Consequently, the meta-

[1] The decoupling point refers to strategic stock that acts as a planned buffer between each side of the supply chain to enable supply chains to cushion the upstream companies from the fluctuating consumer demand (Mason-Jones & Towill 1999, p. 14).

analyses of literature by Ataseven and Nair (2017); Chang et al. (2016) also confirm the same. The authors argue that firms must first focus on forming internal integration prior to attempting to accomplish external integration (Ataseven & Nair 2017; Huo 2012; Yu 2015; Zhao et al. 2011). The claim is that if organisations do not have good internal integration among cross-functional operations, their competence in exchanging information to collaborate with external partners becomes problematic (Huo 2012; Tracey 2004). Su and Yang (2010) argue that successful internal integration is predicated on unifying multiple operational activities into a synergistic process (e.g. cross-functional planning, sourcing, manufacturing and delivery). These foundational cross-functional processes within an organisation should be aligned first, before attempting to engage with external partners (Ataseven & Nair 2017; Childerhouse & Towill 2011). However, some studies (Richey et al. 2010; Stank, Keller & Daugherty 2001) advocate for understanding the interdependencies and propose keeping internal focus and external focus in balance and in focus simultaneously.

The intensity of integration, either upstream or downstream, varies significantly among organisations, resulting in different extended capabilities and performance outcomes (Ataseven & Nair 2017). Huo (2012)'s study grounded in organisational capability theory, found a positive effect of SCI on company performance, in the manufacturing industry context. The study also found that internal integration has a positive effect on external integration. Huo (2012) surmised that internal integrative capabilities are the foundation of external integrative capabilities. However, the findings suggest that it is the internal integrative capabilities that directly contribute to company's financial performance, while neither customer nor supplier integration significantly influences financial performance directly. Rather, customer and supplier integration can improve financial performance via the mediating effects of customer oriented performance and supplier oriented performance, respectively. (Huo 2012). In contrast, Flynn et al. (2010) found that internal and customer integration, rather than supplier integration, are more robustly related to organisational performance enhancement. The studies in general find that internal integration has the greatest influence on performance over supplier and customer integration (Flynn et al. 2010; Huo 2012).

In summary, intense global supply chain competition and market turbulence drive organisations towards SCI (Yan et al. 2014). However, SCI literature is still in its infancy (Alfalla-Luque et al. 2013; Flynn et al. 2010). Childerhouse and Towill (2011) claim that, despite SCI being significantly correlated to performance improvement, in practice, the majority of the supply chains are not integrated properly. However, the expanding global supply chain landscape and the increased presence of specialised external logistics service providers entrusted with the movement and storage of goods has increasingly highlighted the importance of integration processes (Frohlich & Westbrook 2001; Jayaram & Tan 2010). Within this context, ICT is considered to be a powerful technological enabler for SCI through its capabilities to capture, manage, share and link business process related information (Rai et al. 2006; Yu 2015).

2.4 Information and Communication Technology (ICT) and Supply Chain Integration (SCI)

As early forms of ICT, telephone, fax and e-mail were longstanding methods of communication in supply chains (Olhager & Selldin 2004). Supply chain digitalisation originated in 1970s when Electronic Data Interchange (EDI) emerged as the first generation of supply chain information platforms to address the problem of cross-system information exchange and process control. As the supply chain concept emerged in the 1980s, the importance of information exchange for the integration of upstream to downstream gained increasing attention (Cui 2015). The emergence of more sophisticated applications such as Enterprise Resource Planning (ERP) systems subsequently provided the digital foundation for SCI (Arzu Akyuz & Erman Erkan 2010).

Wu et al. (2016) argue that, in the current context, supply chain management would not be even possible without the developments in ICT. Indeed, ICT infrastructure plays a crucial role in improving supply chain management capacity, by reducing interaction and transaction costs and influencing logistics, procurement, vendor and customer relationship management (Aiello, Dulskaia & Menshikova 2016). ICT plays a large role in facilitating effective decision-making to enhance supply chain performance via improved communication enabled by the acquisition and transmission of data (Ben-Daya et al. 2017). The key objective of ICT implementation is to moderate supply chain uncertainty and to reinforce real-time decision making via enhanced quality and speed of information transmission and processing (Prajogo & Olhager 2012). Information sharing systems such as EDI or ERP systems noted above continue to strengthen inter- and intra-firm collaboration and SCI (Acar et al. 2017; Bocquet 2011; Wong et al. 2011a).

A well integrated ICT platform encompasses physical components, standards for data integration, and processes to achieve real-time connectivity between distributed applications

(Rai et al. 2006; Ross 2016). It enables reliable real-time sharing of information between supply chain management related applications and functions distributed across partners (Rai et al. 2006), to facilitate relationships and further integrate business processes (Chiang, Chen & Wu 2014). Therefore, in contrast to conventional stand-alone ICT applications, digital SCI is further characterised by inter-firm linkages (Dong, Xu & Zhu 2009; Vanpoucke et al. 2017).

Notably, ICT enables SCI via an increase in the volume and complexity of information exchange as well as increased visibility of that information across the supply chain (Vanpoucke et al. 2017). The inclusion of ICT for integrated supply chain management may cause superior efficiency and effectiveness (Kim 2017; Narasimhan & Kim 2001). Within this context, ICT plays a critical indisputable role in supply chain management (Ross 2016), shaping the structure of supply chains (Ben-Daya et al. 2017; Zhang, Pieter van Donk & van der Vaart 2011), and assisting supply chains to deal with the challenges of the continually changing global environment and a multitude of risks at all levels. Taking full advantage of the improvements in the ICT sector, new and smarter versions of supply chains seek to establish an intelligent infrastructure for merging data, information, products, physical objects, and business processes together (Wu et al. 2016). Subsequently, there is in-depth literature on supply chain digitalisation (Wu et al. 2016). Accordingly, the effect of ICT on supply chain performance from both management and technological perspectives have been recurrently researched (Vanpoucke et al. 2017; Zhang et al. 2011).

Bharadwaj (2000) draws on the resource-based view (RBV) to develop the concept of ICT as an organisational capability and to empirically examine the association between ICT capability and firm performance. They found that firms with high IT capability outperform others. Parida, Oghazi and Cedergren (2016) also built on RBV for competitive advantage, confirming that ICT capabilities influence different dynamic organisational capabilities in small firms. Benitez-Amado and Walczuch (2012) drew on the perspective of ICT-enabled organisational capabilities to find that ICT capability enables environmental sustainability, to in turn generate business value. Shatat and Udin (2012) study findings indicate that the effective usage of ERP systems can contribute toward improving supply chain performance via integration, material management, production planning and controlling. Qrunfleh and Tarafdar (2014) study on the effect of information systems (IS) strategy validate that the ICT strategy improves the relationship between lean and agile supply chain strategy to impact on supply chain performance, in turn influencing firm performance.

Zhang et al. (2011) literature review of survey studies of key journals in operations management, logistics and information systems found that, despite the different and often incomparable measurements and constructs used for major variables (ICT, supply chain performance), generally, there is a positive direct or indirect effect of ICT on supply chain performance. However, organisational capability theory rejects any direct relationship between ICT and performance, postulating that ICT as a lower order/core capability can only have an effect on performance via its positive effect on a higher order/dynamic organisational capability, in this case, integration (Huo 2012; Rai et al. 2006).

The utilisation of ICT plays a pivotal role by helping supply chain partners to enhance the speed and depth of the information exchange (Vanpoucke et al. 2017). These improved information sharing and processing capabilities can facilitate greater inter-firm collaboration, consequently strengthening SCI (Yu et al. 2016). Thus, the authors consider ICT to be crucial in achieving SCI for performance gains (Näslund & Hulthen 2012). Consequently, many studies have found that ICT enables SCI via strengthening the information flow between supply chain partners (Li 2015; Rai et al. 2006).

Rai et al. (2006) utilise an organisational capability perspective to find that firms that develop ICT infrastructure for supply chain management and leverage the ensuing synchronised information flows with physical flows are able to generate higher-order supply chain process integration capability. In turn, this generates significant organisational performance gains. Specifically, information sharing among supply chain partners create information-based approaches which support the movement of physical products and financial processes. This results in improved performance, particularly in operational excellence and revenue growth. Similarly, Su and Yang (2010) find that ERP enhances operational process integration, customer and relationship integration, and planning and control process integration. Vanpoucke et al. (2017) study points out that the impact of ICT is greater on upstream integration. Yu et al. (2016) also found that ICT capability has a significant positive effect on SCI. Prajogo and Olhager (2012) found that ICT capabilities and information sharing have significant effects on logistics integration, in turn positively effecting overall operations performance. Li (2015)'s results demonstrated that ICT capabilities significantly influences internal, process, and product integration, with internal integration significantly affecting overall operation performance.

The literature shows that ICT implementation impacts performance through its impact on SCI. Li et al. (2009) found that that ICT has no direct effect on supply chain performance, but instead ICT heightens supply chain performance through its positive effect on SCI, to highlight the importance of the mediating effect of SCI. Kim (2017) further clarified that ICT does not have a positive direct relationship with firm performance. The author argues that, in the relationship between ICT and firm performance, a business process-oriented approach, rather than a traditional view of direct association, is necessary in order to use ICT in an effective way. Dong et al. (2009) argue that the technological resources alone do not generate ICT value creation, their adaptations of supply chain processes are what creates value.

Integration and control in virtually integrated supply chains are based on connectivity in the flow of information (Tai, Wang & Wang 2006; van Hoek 1998). In this context, virtual integration is understood as the remote management of physical objects through information flow (van Hoek 1998). Wang et al's. (2006) proposed a virtual integration theory to represent and replace physical objects with information in supply chain management, as a way of improving vertical coordination.

Goodhue et al. (1992) demonstrate that the cost benefits of data integration contextual or situational. While testing the effect of integrating information flows between internal organisational functions and across partner firms is a contributor to organisational competitiveness, based on contingency theory, Wong et al. (2011a) address the effects of situational factors on the success of information integration. The study finds that integrating information flows improves supply chain performance, while the performance outcomes are contingent on both internal operational characteristics and external environmental conditions. The finding highlights that information integration enhances an organisation's ability to perform, particularly under favourable environmental conditions such as in a highly munificent and a less uncertain environment and when durable and complex products are offered.

However, all the above ICT-related digitally-enabled SCI studies consider SCI as a unilateral construct in their tested frameworks. Only Yu (2015) study conceptualise SCI as a multi-dimensional construct in the context of ICT implementation. Examining the impact of supplier, internal and customer related ICT-enabled SCI on operational and financial performance, Yu (2015) found that the greater the investment in ICT, the more likely it is that the firm will achieve internal integration across functional areas. This positively impacts operational and financial performance. Echoing other literature, this internal integration in turn strengthens external integration. The results of the tested conceptual framework indicate positive relationships between ICT and supplier, internal and customer integration.

In summary, as noted above, the common stipulation in the literature is that ICT deployment in supply chains itself cannot generate performance; its alignment and applications along with other orgnisational resources facilitate SCI for positive outcomes (Kim 2017; Li et al. 2009; Rai et al. 2006). However, these studies have been based on generic ICT, therefore they are predominantly grounded on computing systems that are connected to Internet. Traditionally, information flows could not accurately reflect the movement of the material flows in real-time, exacerbated by the difficulty of understanding the processes of supply chain executions in real-time (Ping et al. 2011). However, the evolution of ICT helps bridge this gap to reinforce supply chain management with end-to-end span of control in real-time granularity (Van Breedam 2016). This represents a disruptive transformation effect, propelling supply chain and the logistics management/structures/design into a swift innovative transformation path (Büyüközkan & Göçer 2018).

IoT, as a new genre of ICT, has steadily demonstrated its distinctive identity in the literature as a digital architecture that can sense real-world information anywhere, anytime, at a negligible operational cost, connecting devices to craft greater intelligence (Atzori et al. 2010). This emergance of IoT as digital innovation has revolutionised the integration process, as it applies to all supply chain transactions and related information dissemination (Haddud et al. 2017; Tu 2018).

2.5 The Internet of Things (IoT)

IoT pertains to 'an extension' or 'a new version' of generic ICT (Borgia 2014; Li, Xu & Zhao 2014; Miorandi et al. 2012), an evolution from internetworked computers to internetworked objects (Mattern & Floerkemeier 2010), connecting previously unconnected "things" (Pye 2014). Accordingly, the IoT vision involves connecting anything, anyone, anytime, anywhere, using any path/network or any service (Borgia 2014), with each object having its own Digital Object Identifier (DOI) (Gershenfeld, Krikorian & Cohen 2004; Tu 2018). Therefore, physical things can be accessed from anywhere via the Internet to serve a multiplicity of purposes (Asghar, Kumar & Patra 2015). This ubiquitous computing is represented by increased integration of ICT into individuals' lives and environments.

These pervasive Internet-connected uniquely addressable things (objects) bridge the divide between the physical and digital worlds (Atzori et al. 2010; de Vass et al. 2018). Therefore, Uckelmann, Harrison and Michahelles (2011, p. 1) conceptualise IoT as a "virtual world of ICT integrated seamlessly with the real world things". IoT does this by forming digital counterparts of physical entities (Borgia 2014). Fleisch (2010, p. 3) distinguishes the IoT concept from the "ordinary" Internet (generic ICT), arguing that "the nerve ends in the IoT are small, in many cases even invisible, they are low-end and low energy consumption devices, whereas the nerve ends of the generic Internet or ICT are full-blown computers". Moreover, the author reasons that the number of network nodes in IoT is drastically higher than in conventional ICT ("trillions versus billions"). It is predicted that around 50 billion such devices will be connected globally by the year 2020 via these emerging IoT provisions (Zhou et al. 2015b). Given the potential, IoT has received significant attention from academics, practitioners, media and the public alike (Mishra et al. 2016; Perera et al. 2015). IoT is not a singular novel technology, but rather a collection of several complementary technologies that provide these extended capabilities (Atzori et al. 2010; Lee & Lee 2015). By enabling more devices to be globally interconnected, IoT has transformed the way we live and work (Mohandas & Aravindhar 2017), to be more effective and efficient with novel applications and networking services (Atzori et al. 2012). IoT has the potential to dramatically change our lives by making many "impossible" things possible, by connecting everything on the earth together via the Internet (Tsai et al. 2014). Therefore, IoT is seen as a disruptive technology, due to the fundamental changes it is reported to generate.

IoT uses the Internet as a global platform for devices to communicate, coordinate, compute and dialogue with each other (Miorandi et al. 2012). The capabilities and intelligence of IoT devices is posited to exceed the in-built functionalities of the device itself by using the Internet as a communication infrastructure, storage mechanism and a medium for data processing and information synthesis (Atzori et al. 2010; Miorandi et al. 2012). The vision is that, by building intelligence into them, everyday objects are converted into uniquely identifiable smart objects that are able to collect information from the environment, interconnect with each other through the Internet platform, interact and control the physical world (Borgia 2014). It can also be argued that physical entities provide knowledge through IoT devices (Meyer, Ruppen & Magerkurth 2013). This platform of things establishes a dynamic worldwide network, exhibiting capabilities beyond traditional ICT through its omnipresence enabling data auto-capture (Borgia 2014).

The IoT core concept was pioneered in 1999, when the Auto-ID Center of MIT used radio frequency identification (RFID) tags with a unique electronic product code (EPC) as a tool to identify and track supply chain commodities via the Internet platform (Verdouw et al. 2016). Although IoT originates from RFID, it is now a central element on its own with far-reaching capabilities (Atzori et al. 2010; Borgia 2014). Seizing the foundation from RFID's key capability of unique identification, the notion of IoT has evolved by complementing further competences such as sensory, context awareness, intelligence, pervasiveness, learning ability and automation to reach its conceptualised unlimited potentials (Ashton 2011; Constantinides et al. 2017; Hofmann & Rüsch 2017; Perera et al. 2015; Tallapragada, Rao & Kanapala 2017). As the technology progressed, the scope was broadened to any physical object to serve a multiplicity of purposes, with the identification system stretching out to emergent IP addressing schemes (Gubbi et al. 2013). At present, the notion of a "Thing" has expanded to include any real or physical objects such as sensors, actuators and smart items (Mishra et al. 2016). Technologies such as RFID, sensors and global positioning systems (GPS) can be embedded conjointly into electronic devices or tagged onto physical objects (Borgia 2014). The growing number of technological innovations exploiting IoT technology indicates that the notion is evolving (Del Giudice 2016). At present, the notion of "thing" has expanded to include any real or physical objects such as smartphones, actuators and smart items (Mishra et al. 2016). Therefore, ''Internet-of-Things'' is used as an umbrella term for covering various aspects related to the extension of the Internet into the physical domain, linking digital and physical entities (Ben-Daya et al. 2017).

The vision of the IoT has been heavily energised by statistics and predictions. The US National Intelligence Council (2008) stressed that "by 2025 Internet nodes may reside in everyday-things, food packages, furniture, paper documents, and more". Perera et al. (2015) justify the growth of IoT using recent statistics, asserting that the number of things connected to the Internet surpassed the worldwide population in 2008. Scholars' predictions are at times, are as high as 75 billion IoT devices coexisting by the year 2020 (Riggins & Wamba 2015) or even about 1000 devices per person coexisting by the year 2025 (Borgia 2014). Consequently, 100 billion such devices are predicted to be connected to the Internet by 2030 (Del Giudice 2016).

Atzori et al. (2010, p. 2789) theorise the IoT paradigm as an amalgamation of three key paradigmatic visions. They are "things oriented vision", "Internet oriented vision" and "semantic oriented vision" (see Figure 2.1). The "things oriented" perspective views IoT as a network of identifiable sensing devices providing exceptional visibility of environments and processes. The more "Internet oriented vision" incorporates the device into device communication over the global infrastructure to control the environment and processes and is more advanced than the "things oriented" perspective. The inclusion of the "semantic oriented vision" desegregates the far-reaching and rather empowering vision of IoT, in which the devices gain the ability to reason, to exhibit intelligence and actuate without human interaction (Riggins & Wamba 2015). These envisioned infinite self-management and autonomic capabilities are the ultimate vision and the driver for IoT solutions (Miorandi et al. 2012). Accordingly, IoT architecture encompasses the objects that captures data, communicates with the real world and actuates, the Internet global platform, including cloud that facilitates transmission, and the hosting and processing of data as well as its information synthesis and processing ability (Atzori et al. 2010). Integration of sensing and actuating devices with advanced data analytics presents furthur oppertunities while cultivating a shared protocol for innovative IoT applications (Gubbi et al. 2013).

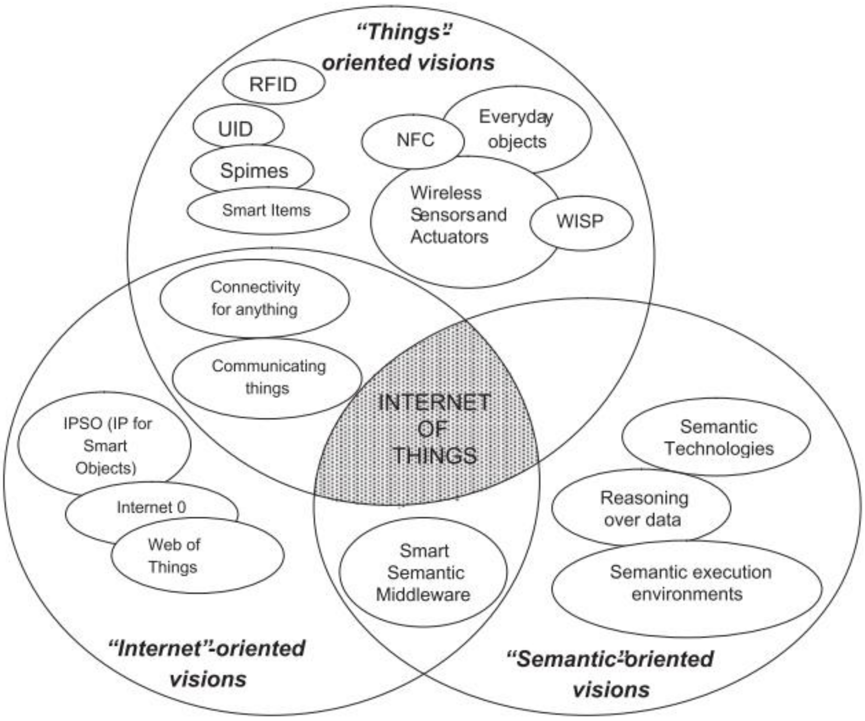


Figure 2.1 IoT paradigm as a result of the convergence of different visions

Source : Atzori et al. (2010, p. 2789)

Only a very small number of the potentialities offered by IoT applications are currently available to our society (Atzori et al. 2010; Lu & Yang 2017). Despite the fact that current application of IoT is reported to be in its infancy stage, in comparison to its broader potential, the ongoing advancements of its fundamental technologies and the efficient integration of these technologies has enabled IoT's wider application through cost-effective miniaturisation (Atzori et al. 2010; Uckelmann et al. 2011). There are an increasing number of devices and objects emerging with sensors to measure a range of real-time data from the environment, and to link such data with other heterogeneous information (Wang et al. 2016).

These new generation smart devices are generally termed ‘product embedded information devices’ (Kiritsis 2011). Lee and Lee (2015) group the five technologies commonly utilised for the deployment of successful IoT-based products as, (i) RFID that allows unique identification; (ii) wireless sensor networks (WSN) to capture environmental conditions; (iii) middleware to support dynamic communication; (iv) cloud computing’s pool of configurable resources (i.e. networks, storage, servers, applications) and (v) IoT applications to receive data, process and act correspondingly. By collectively utilising above five fundamental technologies, IoTs “uniquely identifiable” “anytime anywhere” “real-time present” “interconnected” and “unambiguous” intelligence has emerged to become a large part of our everyday lives (Gubbi et al. 2013; Pang et al. 2012).

The recent proliferation of Internet-connected devices in general and RFID and sensor markets specifically confirm its growth (Perera et al. 2015). As a result, a range of always responsive, innovative services have become available for users (Miorandi et al. 2012) and have changed the way organisations operate with more efficiency and effectiveness (Borgia 2014). However, the current deployment of IoT is reported to be fragmented and lacking in the interoperability necessary to realise its full potential, due to issues concerned with standardisation, architecture, security and privacy, cost and unified approach (Borgia 2014). The literature surrounding IoT is growing, but still underdeveloped (Mishra et al. 2016). Despite the progression, IoT is not widely explored in management and operations academic publications. Xu, He and Li (2014) analysis of over 300 IoT publications found rising interest in IoT in academia. Yet, Whitmore et al. (2014) survey of 127 IoT themed publications revealed that the literature is mostly confined to technology perspectives and IoT is not well represented in the management and operations literature. Liu and Gao (2014) articulate that IoT is still an emerging area of study; therefore, the current IoT literature focuses mainly on concept definitions, model building, key technology and features. Mishra et al. (2016), through a review of 1,556 articles published on IoT from 2000 to 2015, found that the field is dominated by conceptualizations and a few case studies on applications of IoT. Verdouw et al. (2016, p. 125) argue that ‘quantitative studies on the benefits of IoT are not yet available’. Mishra et al. (2016, p. 1348) articulate that, “studies that shift the focus from purely technological to the socio-organisational implications of IoT adoption, would benefit both researchers and managers who would like to further explore IoT”.

Many authors consequently discuss the aspects of IoT through vision, challenges, application and its technological synthesis (Borgia 2014; Gubbi et al. 2013; Lee & Lee 2015; Li et al. 2014; Miorandi et al. 2012). The common conviction among scholars is that IoT can improve the overall standard of living (Asghar et al. 2015). However, Pang et al. (2012) argue that generating maximum value from the on-hand technology needs further attention. Citing the absence of academic evidence, Perera et al. (2014) drew on website information to evaluate 50 key research and commercial solutions from an industrial market perspective in context-aware computing, which represents a crucial IoT attribute in value creation. Tsai et al. (2014) argue that IoT may create a "data deluge" of volume, variety and velocity containing valuable information and, therefore, asserts that there is a critical role for "big data" mining for intelligent IoT systems. Although factors such as ease of use, social influence, perceived enjoyment and perceived behavioural control are reported to stimulate the public to accept IoT (Gao & Bai 2014), they are discouraged by privacy concerns, trust and legal constraints, due to the growing fear of surveillance through manipulation of personal information or "dataveillance" (Winter 2013).

IoT technology is increasingly integrated into new value-added applications (Meyer et al. 2013). Meyer et al. (2013) make a case for integrating IoT into ERP systems architecture to address the limitations of generic ICT in its ubiquity and the dependence of humans for data capture, as IoT devices interact with the physical environment, autonomously of humans. Majeed and Rupasinghe (2017) developed an IoT-enabled conceptual framework for the fashion and footwear sector, to improve inbound and outbound supply chain operations in ERP systems. The authors focus on technologies such as RFID, sensors and actuators to take over process responsibilities. However, despite IoT being widely applied to improve the capabilities of traditional ICT systems, the widespread conceptualisation is that IoT is an independent infrastructure with its own reasoning and reaction ability (Atzori et al. 2010; Luo & Wang 2012; Moreno et al. 2014).

In summary, IoT is envisioned as being one of the most promising technologies to unfold abundant economic opportunities (Hofmann & Rüsch 2017). Both academics and practitioners are confident that IoT provides tangible benefits to society, environment, individuals and organisations (Borgia 2014). The literature discuss healthcare, smart environments (natural environment, smart homes, smart cities), public safety, security and social relationships as some of the key social application domains for IoT. Transportation and logistics, manufacturing, agriculture, utility management, insurances and retail are reported to be some of the main commercial applications (Atzori et al. 2010; Borgia 2014; Del Giudice 2016; Gao & Bai 2014). Supply chain management was the domain the concept IoT was first introduced into (Ashton 2011; Gubbi et al. 2013), and many continue to emphasise supply chain management as a key commercial IoT application domain, with enormous potential in logistics processes (Lee & Lee 2015; Riggins & Wamba 2015). As IoT technologies are becoming more effective and affordable, IoT's deployment in supply chain operations is predicted to grow in response to market challenges (Verdouw et al. 2016).

2.6 The Internet of Things in Supply Chain Management

As it has become challenging to achieve performance improvements via traditional methods with human intervention, most organisations indisputably see the necessity of developing innovative technology-based solutions (Wu et al. 2016). By establishing advanced and sophisticated information systems, firms have been able to improve their competitiveness by overcoming issues such as the lack of information flows in supply chain operations which could not be resolved with the conventional methods of supply chain operations (Cui 2015). Forms of ICT such as IoT provide end-to-end supply chain visibility for supply chain planning and monitoring improving competitiveness (Li & Li 2017; Tu 2018; Van Breedam 2016). For example, RFID reduces inventory shrinkage, avoids excess stocks, prevent stockouts and improves data accuracy and reduces information acquisition costs (Wu et al. 2016). Therefore, there is a growing interest among industry practitioners and academia to observe IoT's computational potential across industries (Perera et al. 2015).

As the IoT platform grows, it is predicted to have a transformative impact on businesses (Mohandas & Aravindhar 2017). As a key application domain, IoT has the capability to transform the way industries operate by connecting them to the digital world (Mishra et al. 2016). Industry 4.0 was a main topic in the 2016 World Economic Forum (Hofmann & Rüsch 2017). This refers to a 'fourth industrial revolution', where the first three are related to mechanical power (Industry 1.0), mass production (Industry 2.0) and digital revolution (Industry 3.0) (Ben-Daya et al. 2017). Ben-Daya et al. (2017, p. 2) argues that IoT is one of the key founding technologies of Industry 4.0. The concept of industry 4.0 as per Zhou, Liu and Zhou (2015a) is the integration of ICTs with industrial technology; the integration of IoT into logistic digitalisation is becoming more and more relevant (Hofmann & Rüsch 2017; Trappey et al. 2017).

IoT technology has been the foundation for many innovative applications in logistics and supply chain functions with potentially far-reaching influence (Tu 2018). "Smart supply chains" involve IoT implementation within a company, and then in global supply chain networks. A smart supply chain can be defined as "the new interconnected business system which extends from isolated, local, and single-company applications to supply chain wide systematic smart implementations" (Wu et al. 2016, p. 396). Since RFID can be tagged on items, cases, and pallets, item-level tagging is the potential standard for a smart supply chain (Tu 2018). The IoT technologies featured would include intelligent infrastructure, with capabilities such as interconnectivity, automated data capture and real-time communication among all supply chain entities, intelligent decisionmaking and efficient and responsive processes, to better serve the customer (Wu et al. 2016).

IoT is percieved to facilitate a paradigm shift in supply chain management (Ben-Daya et al. 2017). Within the supply chain management context, IoT is described as "an emerging global Internet-based information architecture facilitating the exchange of goods and services in global supply chain networks" (Liu & Sun 2011a, p. 1374). Tu (2018, p. 395) claims that "IoT envisions a global infrastructure of networked physical objects that render radical transparency to supply chain management". Ben-Daya et al. (2017, p. 3) supply chain oriented IoT definition is, "IoT is a network of physical objects that are digitally connected to sense, monitor and interact within a company, and between the company and its supply chain, enabling agility, visibility, tracking and information sharing to facilitate timely planning, control and coordination of the supply chain processes".

It is remarked that IoT can sense supply chain entities and the environment through their entire lifecycle (Kiritsis 2011), to improve visibility, accuracy, traceability, interoperability and collaborative decisions in supply chains (Ping et al. 2011; Reaidy et al. 2015). IoT provides a deepening of supply chain communications, with humans to things communication and, autonomous coordination between 'things' during the logistics functions of storage and movement of goods within supply chain entities (Ben-Daya et al. 2017). This contributes to unprecedented visibility into all aspects of the supply chain, which drives supply chain efficiency and effectiveness (Ben-Daya et al. 2017).

By reducing the time between data capture and decision-making, IoT enable real-time responses to changes, and to enable remote management of the supply chain, with improved coordination among supply chain partners and more accurate information for effective performance (Ben-Daya et al. 2017). With more information, smart supply chains can potentially produce better decisions, better processes and better products (Wu et al. 2016). Consequently, IoT can help auto-capture detailed real-world information at a negligible operational cost, and interact with other devices to generate precise intelligence via real-time streaming analytics (Ahlgren, Hidell & Ngai 2016; Mattern & Floerkemeier 2010). IoT not only improves the richness of the information at a lower operational cost, but has also reached places that are humanly impossible due to physical and practical constrains such as restricted spaces, toxic areas or heights (Verdouw et al. 2013). This prompt organisations to respond innovatively in their operations, delivering positive economic and social outcomes (Mattern & Floerkemeier 2010).

Overall, IoT provides deeper and more accurate information, beyond human observation for intense supply chain control (Lee & Lee 2015; Verdouw et al. 2015). These attributes can help monitor, measure, control, automate, optimise and learn (analyse) supply chain activities, entities and processes (DHL 2015), to generate value for all partners through monitoring and control, business analytics, information sharing and collaboration (Lee & Lee 2015) (See Figure 2.2). IoT not only can impart operational and financial performance; it is also an enabler for greater environmental sustainability and increased safety and security by monitoring equipment and people (Ben-Daya et al. 2017; DHL 2015).

Figure 2.2 How IoT helps in supply chain management

adapted from DHL (2015); Lee and Lee (2015)

IoT can be used in logistics functions for identifying, tracking and tracing, monitoring, for real-time responsiveness and to optimise operations (Ben-Daya et al. 2017; Ferreira, Martinho & Domingos 2010). The literature identifies numerous purposes and potentials for

IoT in supply chain management in general and retail supply chains specifically. Current supply chain applications of IoT are reported to take various forms. These include item level product tracking via a unique electronic product code (EPC) with RFID tagging (Tu 2018; Wamba & Boeck 2008); route optimisation and vehicle tracking with GPS related location awareness technology (Atzori et al. 2010; Lu & Yang 2017); measuring a range of environmental conditions via wired and wireless sensors (Thoma et al. 2013); retail store management and customer relationship management through the new generation of smart devices equipped with various built-in sensory capabilities and beacons that can be summoned for a multiplicity of purposes (Yu et al. 2015) and; advanced security and surveillance, transportation, and barcode technology as enhanced aptitudes of conventional mechanisms that are not initially designed to exploit Internet capability (Suresh et al. 2014). More importantly, all the above IoT technologies and their data can be integrated beyond isolated embedded systems to deploy smarter solutions (Atzori et al. 2010; Lee & Lee 2015). The common element is that Internet connectivity has improved the functionality of these product embedded information devices. The discussions however vary from IoT technologies. For example, RFID requires a more unified, standardised and investment-oriented approach (Bardaki, Kourouthanassis & Pramatari 2012), in comparison to the exploitation of widespread smart devices, GPS's and smartphones that come with various built-in IoT functionalities (Chang, Dong & Sun 2014; Perera et al. 2015). Therefore, IoT should not be viewed as a technology limited to large, resourceful organisations and supply chain operations, but rather as a broadly available capability in general.

Scholars have addressed numerous functions for IoT application in the supply chain application domain. Some of them are listed in the below in Table 2.1.

Table 2.1 Reported IoT use in supply chains

No.	Application	Publication
1	Fleet tracking, monitoring of item locations.	Anderseck and Hille (2013)
2	Monitoring storage/shipment conditions.	Lianguang (2014)
3	Allergen detection/quality control of products.	Zhou and Piramuthu (2015)
4	Product tracking for traceability purposes such as food traceability.	Chen (2015); Liu (2015)
5	Managing perishable product supply chains.	Yan (2017)
6	Payment processing based on location/activity duration.	Porkodi and Bhuvaneswari (2014)

7	Fast payment solutions such as automatically check-out.	Fiedler and Meissner (2013)
8	Postponement for customised products.	Ng et al. (2015)
9	Shop guidance according to a shopping list.	Chang et al. (2014)
11	Rotation of shelves and warehouse automated restocking.	Suresh et al. (2014)
12	Returnable asset management.	Gnimpieba et al. (2015)
13	Identifying shopping trends of products that match customer's ideological preferences (e.g. through smart phone applications).	Sánchez-Picot et al. (2014). Magerkurth et al. (2010)

Every firm in general is a producer and a user of information; therefore, firms should grow mechanisms not only to receive information from their supply chain partners, but also capture and analyse much of the internal information and share it externally with partners (Wu et al. 2016). Therefore, IoT adoption helps businesses to be strategic and proactive, rather than reacting to the challenges of a complex market, helping organisations improve their operational performance via an effective management of business processes (Haddud et al. 2017). Within this context, IoT usage in supply chains increases profitability, reduces excess products that loses the value quickly, enables rapid response to changing customer demands or supplier availability and optimises consignments and the assurance of complete, on time deliveries (Haddud et al. 2017).

However, Tu (2018) argues that despite the declining costs of IoT hardware in things like RFID tags and readers in recent years, many firms are still cautious about IoT deployment in supply chain management. A lack of a global standards for IoT is recurrently reasoned to be a barrier for organisations to consider IoT in their supply chain due to lack of potential interoperability among supply chain partners (de Panizza, Lindmark & Rotter 2010; Tu 2018). López et al. (2012) argue that there is a lack of an integrated vision in general regarding how to realise the associated value of IoT. Del Giudice (2016) literature review reveals that easy installation, standardisation, stoutness, configuration and servicing are necessity for IoT systems to add value in business process management in any industry.

In spite of claimed benefits and diffusion, the promise of IoT as a disruptive technology is not widely discussed within the supply chain management domain (Bardaki et al. 2012).

Surprisingly, the existing literature does not provide much guidance on adapting to transformations wrought through emerging technology such as IoT. Little is also written about the socio-economic benefits of emerging technologies. Haddud et al. (2017) argue that despite IoT products and services are no longer in the infancy stage, while more IoT-related technologies and devices are introduced, and firms are progressively adopting more applications, there is still a lack of studies on the general effect of IoT adoption on supply chains or even on different aspects of organisations.

Ben-Daya et al. (2017) explore the role of IoT and its impact on supply chain management through a literature review of 166 publications. The study covers IoT definitions, key IoT technology enablers and various supply chain management processes and applications. The authors found that most studies are concentrated on the delivery element of supply chain processes primarily in food and manufacturing chains. The studies have focused on just conceptualising the *potential* impact of IoT. There are few analytical models and empirical studies published (Ben-Daya et al. 2017).

Even though supply chain management is being discussed as a key IoT application domain, there is only a thin set of devoted publications addressing its relevance (Ben-Daya et al. 2017). Some of the relevant publications on IoT in supply chain are listed in Table 2.2.

Table 2.2. Publications centred on IoT application in supply chain management.

No	Theme	Authors
1	Supply chain strategies	Ping et al. (2011)
2	Supply chain decision making	Zhang et al. (2014)
3	Supply chain collaboration	Reaidy et al. (2015); Zhong and Zhong (2013)
4	Supply chain innovation	Li and Li (2017)
5	Supply chain traceability	Zhou and Piramuthu (2015)
6	Food safety supply chain traceability management	Chen (2015); Liu (2015)
7	Tracking and tracing returnable assets	Anderseck and Hille (2013)
8	Tracking pallets and containers	Gnimpieba et al. (2015)
9	Reverse supply chains	Parry et al. (2016)
10	Closed-loop supply chain management	Kiritsis (2011)
11	Mass customisation	Ng et al. (2015)

12	Agricultural supply chains	Gu and Jing (2011); Kaloxylos et al. (2013); Lianguang (2014); Srinivasan, Shanthi and Anand (2017); Wang and Liu (2014); Zhang (2014)
13	Green agricultural products supply chain management.	Li (2011)
14	Product authentication and tracing and tracking products in the supply chain on combating counterfeits.	Li (2013)
15	Supply chain resilience.	Cui (2015)
16	Smart storage system architecture.	Liu and Geng (2016)
17	End-to-end cold chain supervision.	Thoma et al. (2013)
17	Smart factory.	Li (2016)
19	Logistics application.	Ruan et al. (2012)
20	Transport logistics.	Ming (2011)
21	Third-party logistics (3PL)	Liu and Sun (2011b)
22	Fourth party logistics (4PL)	Tian et al. (2011)
23	Smart shelf	Satapathy, Prahlad and Kaulgud (2015); Vargheese and Dahir (2014)
24	Dynamic pricing updates in retail	de Rivera et al. (2014)

However, Tu (2018) explored the determinants of IoT adoption intention in logistics and supply chains among Taiwanse firms across multiple industries, by collecting data from managerial staff using a mixed methods approach. The findings of the qualitative study identify issues regarding firms' intentions to accept or reject IoT . The resulting quantitative framework indicates that perceived benefits, costs, and external pressures determines IoT adoption. While the trustworthiness of the technology does not have a direct link, it indirectly influences IoT adoption intention via perceived benefits.

There are some interesting publications that conceptually and technically place IoT within the supply chain context. Dweekat and Park (2016) put forward an IoT-enabled supply chain performance measurement model to monitor, manage and control supply chains in real-time, in a more integrated manner. Fiedler and Meissner (2013) report a case of IoT practices in retail and logistics. Musa et al. (2014) examine the design challenges for the integration of IoT technologies for advanced logistics operations and demonstrate the feasibility of an embedded microsystem that combines RFID, GPRS, GPS and environmental sensors. The research published by Burke, Quigley and Speed (2013), based on a single case study of a food retailer, finds that customers are more inclined to buy tagged items. Bardaki et al. (2012) document the lessons learnt about IoT during the deployment of two retail RFID applications for dynamic pricing and management of promotions on a supermarket floor. Pang et al. (2012) conducted field trials and a prototype of a three-tier information fusion system for accelerated data processing, self-learning, shelf life prediction and real-time supply chain re-planning. Meanwhile Luo and Wang (2012); Vargheese and Dahir (2014) propose smart IoT architectures for retail stores, Winter (2013) attempts to identify and understand the ethical dimensions of such practices that are perceived as privacy violations to argue that surveillance via IoT creates an imbalance between the shopper and the retailer that also may impact individual autonomy. Gong and Tian (2012) articulate that, in a self-perpetuating model such as IoT, customer value improves continuously, with more members joining in to create more value to the entire value chain. The reported rewards are not restricted to financial gains but further extend to environmental and social implications (Borgia 2014; Miorandi et al. 2012).

However, there is a lack of quantitatative empirical findings to prove IoT's benefit to supply chains (Verdouw et al. 2016, p. 125). The scholars argue that quantitative method is the key research approach for studying the theme of technology adoption (Tu 2018). As one of the few quantitative studies available, Haddud et al. (2017) beginning on the assumption that IoT facilitates SCI, surveyed academics across multiple countries. The academics were asked to rate the importance of an identified list of potential benefits of IoT to organisations and specifically, the organisation's supply chain. The highest ranked benefits to organisations were more transparency and visibility of information and material flows, improved product tracking and traceability, better control and management of inventories and improved integration of internal business processes. Perceived benefits to the supply chain were development of real-time supply chain management, reduction of data distortion, improvement of business intelligence, reduced delays in data collecting, assessing and acting, and importantly, better internal integration, followed by SCI with external partners. The key potential challenges for organisations in IoT implementaion were potential device and network security risks and vulnerabilities, and the lack of a clear comprehension about IoT benefits. Other challenges included integration along multiple supply chains with varied technologies and data services, and the lack of global standards of IoT communication protocol for smart objects and systems. Top management commitment, development of effective supply chain management strategy, devoted resources for supply chain, logistics synchronisation, use of modern technologies, information sharing with supply chain members were perceived to be the key supply chain management critical success factors of IoT adoption.

IoT studies are still emerging (Liu & Gao 2014), and IoT is rarely addressed from the management and operations perspective, particularly with respect to the retail industry (Whitmore et al. 2014). Literature on the use of IoT in retail supply chains in specific or logistic supply chain application in general is restricted to model building (de Rivera et al. 2014; Liu et al. 2015; Liu 2015; Liu & Gao 2014; Majeed & Rupasinghe 2017; Pang et al. 2012; Qin et al. 2015; Thoma et al. 2013; Vargheese & Dahir 2014), concept papers (Gong & Tian 2012; Lianguang 2014; Magerkurth et al. 2010; Ng et al. 2015; Ruan et al. 2012; Sánchez-Picot et al. 2014; Zhang 2014; Zhou et al. 2015b) and simulations (Chen 2015; Juntao et al. 2013; Musa et al. 2014).

Importantly, despite conceptualising the potential impact of IoT, authors have failed to validate its effect via analytical models or empirical studies from the industry perspective (Ben-Daya et al. 2017). Mishra et al. (2016)'s literature review of 1,556 published IoT papers from 2000 to 2015 also confirmed the domination of conceptualisations and the presence of a small number of case studies on IoT applications. The paper also confirms that despite large interest from academics and the practitioners, the greater part of the literature is framed from technology perspectives and there are no studies on the relationship between IoT adoption and improved supply chain or firm performance.

In summary, supply chains are progressively more virtualised via the extended capabilities of ever more affordable IoT technologies (Tu 2018; Verdouw et al. 2013), addressing the information gap in existing supply chain technology (Liu et al. 2015). Information services based on IoT help to integrate information and physical flows to optimise supply chain management (Papert & Pflaum 2017). Therefore, IoT is predicted to be the foundation for the development of novel business models by capitalising on its pervasiveness and ubiquity (Whitmore et al. 2014). However, thus far the academic literature contains insufficient empirical evidence on the effect of IoT on supply chain performance (Ben-Daya et al. 2017). Haddud et al. (2017) argue for IoT adoption in supply chains which is lacking at the moment in many firms. As a technological extension of traditional ICT capabilities (Borgia 2014), IoT is theorised to have influence on supply chain performance through its integration capabilities (Li et al. 2009; Rai et al. 2006). Although SCI is an underlying concept in supply chain studies (Childerhouse & Towill 2011; Frohlich & Westbrook 2001), scholars have made little attempt to credit or acknowledge SCI in an IoT context. IoT's ability to support SCI by improving the performance remains unexplored. While IoT is spoken of enthusiastically as a way to revolutionise supply chain operations by bettering performance (Ben-Daya et al. 2017; Verdouw et al. 2013), this vital mediation link between IoT capability and supply chain performance is gotten largely ignored. “It would be very interesting to investigate how information and material flow interactions produce any new value in the smart supply chain setting” (Wu et al. 2016, p. 408).

2.7 The Internet of Things and Supply Chain Integration – the Gap

As discussed above, ICT is vital for supply chain management in responding to a dynamic global environment and mitigating risks at all levels. ICT has the capability to internally integrate a firm’s various cross-functional processes as well as external processes with suppliers and customers (Del Giudice 2016; Yu 2015). While information availability in real-time and communication (supply chain visibility) is mandatory to achieve integration (Van Breedam 2016), digital SCI is growing to be increasingly dynamic (Korpela, Hallikas & Dahlberg 2017). Much as the Internet connects computers, IoT can potentially connect most products, machines and people together (Li & Li 2017). Supply chain information systems based on IoT are capable of coordinating and integrating internal and external activities of enterprises (Cui 2015). Therefore, IoT, as one of the latest ICT revolution with new levels of supply chain visibility, is argued to be providing a paradigm shift within this context, taking supply chain communications to another level, to more effectively cope with various supply chain management challenges (Del Giudice 2016).

IoT’s automated capacity to identify and rapidly respond to the events in the physical world in uncovers new possibilities for the management of complex situations, and enables various business processes to be optimised (Mattern & Floerkemeier 2010), modified, or for new business processes to be established (Meyer et al. 2013), consequently improving visibility, accuracy, traceability, interoperability and collaborative decisions in managing supply chain processes (Reaidy et al. 2015). Therefore, from a business process management viewpoint, value creation from the IoT technologies is becoming pivotal in the industry, on a progressively higher scale (Del Giudice 2016). While the topic is growing progressively fervent in the managerial literature there is only a thin set of analytical models and empirical studies available. As such, the scope of IoT’s impact on supply chain processes is unknown (Ben-Daya et al. 2017).

Supply chain management above all focuses on the integration of business processes at strategic, tactical and operational levels (Alfalla-Luque et al. 2013; Verdouw et al. 2013). In view of the assertion that “IoT was originally proposed for the SCI” (Wu et al. 2012, p. 245), SCI is perceived to be greatly enhanced with IoT proliferation (Haddud et al. 2017; Wakenshaw 2017). IoT is a new and disruptive technology, affecting organisations and supply chains, through the flow of end-to-end information essential to understanding and managing supply chains (Fawcett & Magnan 2002).

As evidenced by the review above, Haddud et al. (2017)’s earlier study was grounded on the notion that IoT is an enabler for SCI to identify internal integration and SCI among key benefits for organisations and supply chains respectively. However, the study conducted within the academic community does not provide any empirical relationships between IoT and SCI. While a small number of scholars have acknowledged the effect of IoT on SCI in their studies (Cui 2015; Haddud et al. 2017; Tu 2018), a few authors from different perspectives have addressed the effect of IoT on SCI for improved performance in a deeper way. They do this by proposing models or empirically testing claims. However, empirical studies are rare.

Among the sparse number of studies, Ping et al. (2011) conceptualisation provides a detailed account on how IoT bridges the gap between physical and virtual worlds, to strengthen the connection between the physical flow and the information flow. Although the discussion is limited to RFID and wireless sensor networks (WSN) as key forms of IoT, this paper is to date one of the only salient conceptualisations which attempted to address the role of IoT, as an extension of the internet, acts as an enabler for SCI. The authors argue that IoT can achieve ubiquitous connections between objects, auto-capture information and process in real-time, therefore, speeding up the information flow. The material flow can be tracked and traced over that information flow to better identify what is happening in the supply chain to construct an accurate and real-time representation of supply chain entities in information systems to help optimise the supply chain process to improve performance via improved agility and responsiveness. The discussion places emphasis on agility, and therefore does not represent the broader performance outcomes. Even though a distributed architecture (model) for supply chain management over the IoT is proposed, no attempt has been made to empirically validate the relationship between IoT and SCI.

As modern logistics cover all links in a supply chain, integrated logistics services are important (Liu & Gao 2014). Liu and Gao (2014) argue that with the integrity and complexity upturn of logistics service outsourcing, logistics firms set customers’ logistics needs as a foundation upon which to build a complete supply and demand process. The authors conceptualise the effect of IoT on service flow, information flow and fund flow in a logistics service supply chain and the effect on its structure by proposing a logistics service supply chain architecture (model) based on IoT. The authors suggest that IoT makes the services provided by the logistics service supply chain more intelligent, faster and more convenient, visible and flexible. IoT is argued to affect information flow by achieving high speed transmission, intelligence for processing, networking for the dissemination and the credibility of information. The reported effect on the flow of funds is through the acceleration the turnover of the funds, ensuring safety and transparency and reducing the financial risks for node enterprises. The authors argue that applying IoT expands information sharing and integrates the material/service flow, information flow and capital flow. The three flows interact to be an organic entity, to improve logistics service capability and operations performance.

Reaidy et al. (2015) IoT infrastructure for collaborative warehousing with a bottom-up approach was proposed with the assumption that the new environment demands supply chains with greater integration. The objective of the proposition is to improve reaction capabilities of order fulfilment through a model based on RFID, ambient intelligence and multi-agent systems. The authors attempt to describe how IoT can facilitate integration from the perspective of a supply chain technology, ambient intelligence and real-time information sharing. The study finds that IoT as an ICT with greater capabilities can further improve SCI. Although empirically validating the claim was not the objective of the paper, the notion that IoT improves SCI was applied to rationalise the proposed multi-agent architecture (model) to improve reaction capabilities of decentralised management of warehouses.

Cui (2015) argues that supply chain resilience represents the immune system of the supply chain to achieve robustness and stability. The author proposes a model thereby improving supply chain resilience is aligned with the deployment of IoT to integrate internal and external supply chain processes. By reasoning that the 'fragility' of supply chain operations caused by the continuous pursuit of greater efficiency cannot be neglected, he claims that IoT-enabled supply chain may turn out to be a simple and secure strategy to ultimately improving customer satisfaction.

Some of this fragility and inefficiency may stem from what Yan and Huang (2009) identify as an information transmission lag in the traditional approach to global supply chain management. Based on IoT, the paper proposes an information transmission model for supply chains and designs a network structure diagram and an information retrieval flow chart. The study takes pharmaceutical supply chains as an example to analyse an application model of IoT in a drugs supply chain to fulfil its information retrieval. They argue that the proposed model can effectively solve the information asymmetry predicament in supply chains, by achieving a supply chain information transmission network.

Some authors have highlighted the information flow perspective. Liu and Sun (2011a) analyser literature to propose an inbound third-party logistics model to manage an automobile parts vendor managed inventory (VMI) system via the information flow formed by IoT. Yet again, the objective is model building by means of employing the notion that IoT is an ICT infrastructure facilitating a secure and reliable exchange of information between things. Liu and Sun (2011b) again use the same notion to explore the literature on 3PL, information flow and IoT to investigate and model an information flow model for 3PL, based on an IoT ecosystem.

In contrast to IoT being perceived as a technology perspective, Pang et al. (2012, p. 292) argue for IoT from the viewpoint of "what information is essential from the business point of view" and "how should the information be provided by the technology". The authors reason that the information collected by various sensors can be synthesised to create more value. To capture more opportunities, the study concludes that the system paradigm must be extended to value-centric design, from the traditional traceability-centric design. The argument is coherent with SCI despite not acknowledging the concept; they converge on how the captured data should be exploited to better manage food supply chains. From a business process management perspective, value creation by IoT application is crucial to encourage progressively greater IoT dispersion within the industry (Del Giudice 2016).

The agriculture industry supply chain is an example of a time-sensitive and high-risk chain, associated with food security, demanding high levels of SCI and supply chain control (Yan et al. 2016). Therefore, timely and accurate information sharing techniques is vital for monitoring and tracing product information across the entire supply chain of agricultural products (Feng et al. 2013; Papetti et al. 2012). Gu and Jing (2011) propose three distinctive applications of IoT in fresh agricultural product supply chains. They are perfecting the monitoring of fresh agricultural products, strictly controlling food security sources, and building a management information system of fresh agricultural products. The proposed system was grounded on the concept that IoT increases SCI. While arguing that IoT is expected to revolutionise the agriculture sector, Kaloxylos et al. (2013) present an overall vision for data integration throughout an agricultural supply chain. Lianguang (2014) proposes a supply chain model for traditional agricultural products, with enhanced quality and safety, by arguing for strengthened SCI via improved information flow with the deployment of IoT. The authors claim that the proposed model may transform passive production into active production, allow distribution to be conducted by 3PL's, lowering the dealing cost circulation process, realising quality management. Yan et al. (2016)'s study also seeks to solve the problem of inefficient information sharing and poor transmission quality in agricultural supply chains. The study introduces an IoT application model for agricultural supply chains to control the quality and the safety of agricultural products via information sharing. The authors argue that IoT can help agricultural product operators establish an inspection and delivery system to enable them to trace the flow of products to efficiently manage production problems.

In line with the virtual integration theory proposed by Wang et al. (2006), another group of authors (Verdouw et al. 2015; 2013; 2016) explored IoT from the object virtualisation perspective of creating digital counterparts of supply chain entities. IoT acts as a virtual technology enabling supply chain members to monitor processes remotely in real-time to control, plan and optimise activities (Verdouw et al. 2013). The flow of information in the virtually integrated supply chain suports connectivity (van Hoek 1998, p. 509), allowing for greater autonomy (Tai et al. 2006), by removing place, time and human observation constraints (Verdouw et al. 2015). These integrated models transcend the boundary between the digital and physical worlds in a dependable, safe, secure, efficient and real-time fashion (Dillon et al. 2012). Verdouw et al. (2013) define and describe the concept of virtualisation from different perspectives to assess how the IoT concept can be drawn upon to heighten the virtulisation of supply chains in the floricultural sector. The authors argue that virtualisation could have a large impact in this sector which includes international growers and customers and develop a conceptual framework that was applied to analyse the Dutch floriculture sector. Based on these multiple case studies, Verdouw et al. (2015) then propose a control model for object virtualisation in supply chain management. Subsequently, Verdouw et al. (2016) analyse the concept of virtual food supply chains, from an IoT perspective to propose an architecture as applied to a case study of a fish supply chain. They argue that IoT-enabled food supply chains can be self-adaptive wherein smart objects operate, decide and learn autonomously. The concept represents a strengthening the information flow to reflect the physical flow via real-time data transmission and processing for supply chain decision-making. Therefore, this object virtualisation concept somewhat harmonises with the SCI conceptualisation.

Yan et al. (2014) study on the Cloud of Things (CoT), which represents IoT on a Cloud platform, tested the relationship between IoT and SCI. The authors argued that the incorporation of IoT and Cloud technologies can strengthen SCI by providing suitable services to interact with the surrounding environment and applying advanced big data analytics to collected data. The conception is coherent with IoT, except for the fact that the Cloud technologies (servers, storage, applications) are elements of Internet services, and are one of the five fundamental technologies of IoT (Lee & Lee 2015), conceptualised under the IoT vision by many scholars (Atzori et al. 2010; Gubbi et al. 2013). However, the conceptualisation embraces a broader vision of IoT (Atzori et al. 2010), in contrast to Ping et al. (2011) Internet-oriented inclination. Furthermore, Yan et al. (2014) argue for IoT as a solution for the limitations of existing ICT to establish the significance of the IoT. The study articulates that sensing operational conditions in real time via IoT can strengthen SCI. Yan et al. (2014)'s argument is consistent with scholarly articles on the same theme (Ping et al. 2011; Reaidy et al. 2015). Subsequently, the study tests a prototype of a supply chain in controlled laboratory conditions. The findings confirm that IoT is an effective approach for SCI, providing intelligent support for physical resource management to achieve overall supply chain performance. However, this research is conducted in laboratory conditions and lacks testing in complex operational environmental outcomes. As it is a single case, deprived of broader perspectives, this pioneering study does not offer adequate empirical evidence from which to generalise about IoT's ability to strengthen SCI.

Wakenshaw (2017) currently explores supply integration in the supply chain network enabled by IoT. The IoT-enabled SCI framework used in this ongoing empirical case study project was published with the preliminary findings. Applying the case study method, the author investigated the technical and business applications of IoT in supply chain operations and its capability to interface with process integration within the Collaborative Planning, Forecasting and Replenishment (CPFR) reference model (Holmström et al. 2002). The preliminary findings reveal that, potentially, SCI could be significantly enhanced by IoT data.

Although studies of IoT are scarce, a few studies do test RFID use for SCI. Wamba and Boeck (2008) advocate for RFID as a "new wave" of ICT that can provide "end to end information flow" between supply chain members. The scant empirical research on the integration ability of RFID could be an indication that, although RFID application reaches back to the Second World War (Landt 2005), it has not sufficiently proliferated to allow generalisation on its benefits in isolation. Angeles (2009) pilot survey research on the perceived ability of RFID on ICT infrastructure to support SCI and the predicted deployment outcomes indicated partial support for its entire hypothesis. Wamba and Boeck (2008) tested RFID in a laboratory setting and, later, (Wamba 2012) in a single case study based on laboratory methods to validate that RFID synchronises information flow with physical flow for improved SCI.

Overall, the academic literature does not provide enough empirical evidence on the relationship between IoT and supply chain performance, or the effect of IoT capability on SCI—the mediation link theorised to be paramount for supply chain performance. However, there is emerging consensus about this omission (Ben-Daya et al. 2017, p. 1; Mishra et al. 2016, p. 1346; Verdouw et al. 2016, p. 125).Therefore, an empirical examination on whether IoT can strengthen SCI to influence performance in the Australian retail industry could address the identified knowledge gap.

In summary, the speed of evolution in ICT is important for supply chain management: the faster the information flow, the more reactive and adaptive the flow of goods will be (Van Breedam 2016). Although SCI is significantly correlated with increased performance, the majority of supply chains are not well integrated in reality (Childerhouse & Towill 2011). IoT's intelligent platform is reported to facilitate efficient and responsive supply chain processes with greater intergration to contribute econimic benefis but also socio-environment implications (Borgia 2014; Wu et al. 2016; Yan et al. 2014). Given the prevailing enthusiasm for technological solutions that enable transparency and visibility to achieve sustainable supply chain outcomes both economically and environmentally, research on the effect of IoT within this context is timely and necessary (Dubey et al. 2017; Mishra et al. 2016). Literature to date is lacking a framework-based empirical study that has investigated IoT-enabled SCI to improve the supply chain and firm performance. Therefore, this study seeks to explore the effect of IoT capability on SCI that eventually can improve performance outcomes.

2.8 Organisational Capability Theory

Earlier studies on SCI have drawn on various theoretical perspectives such as resource based view theory (RBV) (Prajogo et al. 2016), transaction cost economics (Jayaram & Tan 2010), coordination theory (Jayaram, Tan & Nachiappan 2010), organisational capability theory (Huo 2012), innovation theory (Wamba 2012), organisational learning theory (Yu et al. 2013), contingency theory (Flynn et al. 2010), or supply chain integration theory (Danese &

Romano 2011). These studies addressed the critical role of supply chain integration (SCI), and further established the relationship between SCI and performance from the perspective of above theories. From the organisational capability theory perspective, which is broadly related to the resource based view theory, ICT resources cannot have the capacity by themselves to create sustainable performance within an organisation (Huo 2012; Rai et al. 2006). A well-integrated ICT infrastructures merged with business processes may develop higher-order capabilities for operations and workflow coordination, demand sensing and optimisation of resources (Rai et al. 2006). Accordingly, this study conceptualises IoT as technologies that can act as additional resources and capabilities to achieve competitive advantages, similar to ICT capability as argued in the literature (Newbert 2007; Peng, Schroeder & Shah 2008). These capabilities are likely to facilitate internal and external communication and information flows in a more integrated way. IoT adoption thus can add to the existing configuration of the ICT capability of an organisation. This study, therefore, intends to develop an insight from the litereture that organisations can build additional capabilities by adopting new and emeging technologies, IoT in this case, into the mainstream business processes which are already running on the legacy ICT backbone. Organisational capability theory, therefore, is an appropriate theory to underpin this research.

Organisational capability (OC) theory is derived from the resource-based view of the firm, where resources and capabilities are mobilised in various configurations for competitive advantage (Huo 2012). The theory proposes that "a firm must develop capabilities to acquire, integrate, reconfigure and release resources that are embedded in their social, structural and cultural context" (Rai et al. 2006, p. 227). Capabilities are an organisation's anticipated or accomplished competitive performance or operational strengths (Peng et al. 2008). Organisational capabilities directly or indirectly affect firm capacity for creating value and gain performance outcomes (Huo 2012). Grant (1996, p. 377) argue that organisational capability can create value through effective transformation of inputs into outputs.

There are various organisational capabilities identified as "core" or "dynamic" capabilities (Huo 2012; Wade & Hulland 2004). Core capabilities are conceived of as unique individual units of competencies within relatively stable environments. Dynamic capabilities suggest the ability to build, integrate, structure, and reconfigure both internal and external competencies to respond to dynamic or unstable environments, to simultaneously produce multiple sustained competitive capabilities (Huo 2012; Peng et al. 2008; Wade & Hulland 2004). Accordingly, local capabilities are generally considered to be core capabilities, while architectural and process capabilities are considered mainly to be dynamic capabilities (Huo 2012).

Verona (1999) explains that internal capabilities include internal communication, process integration, job training etc., while external capabilities represent external communication and networks of partners. Integration *per se* is a higher order/dynamic process capability that can directly influence firm performance (Huo 2012; Rai et al. 2006). Internal and external information sharing (Huh et al. 2008)(Huh et al. 2008)(Huh et al. 2008)(Huh et al. 2008)(Huh et al. 2008), communication (Huh et al. 2008; Kusunoki et al. 1998), and inter-firm relationships (Lorenzoni & Lipparini 1999) represent a firm's process integration capabilites. OC theory suggests that internal integration capabilities can directly affect external integration capabilities, where internal process management is the foundation for the development of the company's external process management. This is because a culture of information exchange and partnership can disseminate from within the organisation to the entire supply chain (Huo 2012; Zhao et al. 2011). As noted in the earlier discussion, firms must first develop internal integration capabilities, prior to engaging in any meaningful external integration (Zhao et al. 2011). Consequently, SCI capability requires the focal firm to integrate complementary flows of materials, infomation and finances with supply chain partners (Rai et al. 2006).

Bharadwaj (2000) argues that ICT implementation itself cannot have a direct effect on performance; rather it needs to be blended with the other organisational resources (e.g. human and financial resources) for performance improvement. ICT must be integrated with other organisational capabilities to achieve competitive advantage within the value creation process (Carmichael, Palacios-Marques & Gil-Pechuan 2011). Therefore, ICT integration for supply chain management represents a lower-order capability to be leveraged to foster the higher-order capability of integration, which can contribute to sustained performance improvements (Rai et al. 2006). Rai et al. (2006) applied the same view in their ICT-enabled integration study. Correspondingly, Parida et al. (2016) found that ICT capabilities influence dynamic capabilities. Thus, ICT is a lower-order/core capability to enable a higher-order/dynamic organisational integration capability to influence performance (Huo 2012; Rai et al. 2006). Hence, IoT can be thought of as improving the intgeration capability of an organisation the way ICT does.

In summary, from the organisational capability theory perspective, internal capabilities (e.g. ICT, human resources) can directly influence external integration capabilities (i.e. supplier and customer processes). Thus firms can use internal ICT as a base on which to develop external ICT resources (Huo 2012).

2.9 Australian Retail Industry and IoT: the context

Retail is an intermediary between the manufacturer and the consumers in a supply chain (Majeed & Rupasinghe 2017). Retail is defined as "sale for final consumption" and excludes sale for further sale or processing (Bhattacharyya 2012). Contemporary retailing is not restricted to selling products and services in various bricks-and-mortar retail outlets, but also through online presence and both (multi-channel, omni-channel) (Majeed & Rupasinghe 2017).

Retail supply chains are extremely intricate due to the array of sales and storage settings, with an unpredictable demand for a vast number of stock keeping units (SKUs) (Popli et al. 2013). A number of specific supply chains at the backend for each category of products, make the right product available at the right place, at the right time, at the right cost to the right customer (Popli et al. 2013). Superior customer orientation and operational efficiencies are necessary to survive in the increasingly competitive retail industry (Hübner et al. 2013) through efficient logistics and order fulfilment (Ellram, La Londe & Weber 1999). E-commerce in the form of e-tailing has exponentially grown to challenge the traditional bricks-and-mortar model, resulting in several retail forms co-existing to provide choices to global consumers (Balazs & Zinkhan 2003). Natural selection theory or "survival of the fittest" vindicates the transformations of the retail landscape (Balazs & Zinkhan 2003), hence progressive technology adoption is crucial (Doms, Jarmin & Klimek 2004).

Due to the dynamic competitive environment in the retail domain with unpredictable consumer behaviour, retail companies are facing various challenges that pose major threats to the prevailing business models (Majeed & Rupasinghe 2017). Therefore, retail experts emphasise the benefits of integrative approaches (Hübner et al. 2013). Connectivity, collaboration and the use of advanced technology are some key areas that retailers must focus on to better manage supply chain intricacy and remain competitive in this digital era (Majeed & Rupasinghe 2017). As retail supply chains are primarily demand driven (van der Vorst et al. 2016), intense ICT-enabled connectivity and coordination within the supply chains are crucial (Aiello et al. 2016). Hence, both scholars and industry practitioners affirm that IoT plays a significant role in the retail space, as IoT can provide more accurate real-time information (Gubbi et al. 2013; Sharma 2014).

IoT can help manage retail supply chains by tracking merchandises and entities to orchestrate supply networks in accordance with customer response (Lee & Lee 2015). Integrating with consumers' mobile phones has become an important aspect of consumer experience, presenting retailers with a novel business concept to market their products (Gehring et al. 2011). Despite the strong interest among major Australian retailers (Wamba & Boeck 2008), there is insufficient insight or guidance for industries to favourably deploy IoT strategies to achieve operational excellence (Hwang, Kim & Rho 2015).

Over 130,000 retail businesses were registered by the end of June 2017 in Australia as classified under Australian and New Zealand Standard Industrial Classification (ANZSIC), 2006 Division G: Retail Trade (ABS Counts of Australian Businesses 2017). Retail trade includes units mainly engaged in purchase and/or on-selling, commission-based buying, and commission-based selling of goods, without significant transformation, to the general public (ABS_ANZSIC 2013). Detailed division G classification includes non-store retailers or e-tailers and excludes wholesalers. The revenue of this industry sector is 2017 A$565.1 billion and employs 1,925,676 people (IBIS World 2018). The retail industry accounts for a significant part of Australian economic activity, representing around 4.1% of gross domestic product (GDP) and 10.7% of total employment (Productivity Commission 2011). Retail sector employment and wages are struggling to keep pace with other industries, due to intense competition and low turnover growth compelling operators across the sector to slash expenditures (Delloitte Retail Report 2017). Historically being one of the biggest employment generators across the Australian economy, employment has only grown by 3.7% from 2012 to 2017, roughly around half of the employment growth across all industries at 7.3% (Delloitte Retail Report 2017).

The Australian Industry Report published by the Department of Industry Innovation and Science (2016) calls for growth in labour productivity, energy efficiency and innovations in business processes. The report argues that, by international standards, Australian firms are slow adopters of technology and, on several digital engagement indicators, Australia ranks in the middle among advanced economies, rather than at the forefront. The report reveals that Australia's productivity has been lagging, while the input cost share of labour in Australian retail is as high as 68.6%. Digital maturity is advocated as a solution. Moreover, using current measures of digital maturity, many Australian businesses lag in *sophisticated exploitation* of digital technologies, with small and medium-sized enterprises (SMEs) further lagging behind their larger counterparts. However, the report claims that the rapid advances in technology and the use of combinations of new technologies mount a significant challenge in measuring the extent of utilisation of digital technologies in Australian businesses.

Government-commissioned reports highlight that digital technology may perhaps be having a much larger impact on economic growth than estimated. A report commissioned by the UK government (Bean 2016) suggests that the contribution of digital economy is underreported in formal statistics, as conventional measurements of GDP, developed at a time the economy was dominated by goods and services, cannot fully account for the influence of digital technologies. The report asserts that "policy makers need stronger evidence of the link between digitally mature firms and productivity" (Department of Industry Innovation and Science 2016, p. 88). In Australia, a report on "IT use and Australia's productivity" by the Bureau of Communications Research (2016) reveals that digital technologies are generating different productivity effects across Australian industries. While ICT substitutes unskilled labour, skilled labour can exploit ICT to a positive effect. It claims that, along with the US, Australia was quick to reap benefits from ICT. The report points out that innovative use of ICT playing an important role in Australia's productivity growth in the 1990s, following a raft of microeconomic reforms. The retail sector was one of the key obvious exploiters. The report also points to international evidence revealing ICT's productivity gains, although they are not uniformly realised. The report states that ICT progress in new forms, and being more pervasive, possibly opens-up new productivity opportunities but may not show up as they don't fit the standard measurement techniques. The report argues that technologies such as IoT are a very much a part of the digital transformation; however, measuring the effect of these digital technologies on productivity has become much harder, as they are more sophisticated and pervasive (Bureau of Communications Research 2016).

Industry-commissioned reports also convey similar findings. A report sponsored by Microsoft (Telsyte 2015) is the only source with Australian industry statistics on IoT currently available. The paper indicates that 26% of 306 Australian cross-sector organisations surveyed have deployed IoT, out of which the two-thirds that measured outcomes have managed 28% cost reductions. 27% of surveyed organisations plan to implement IoT within the next two years with cost-cutting and process improvement being the major drivers. The study substantiates that retailers have made the greatest progress via big data solution deployment statistics. Transport & storage services that play a major part in retail supply chains are considered to be early movers. Although the report includes survey data from 37 retail firms, it does not specify IoT deployment in retail explicitly, nor does it look at how IoT blends with business process to impact on SCI for performance gains. However, referring to the same data, an industry website (Inside Retail 2015) claims that half of retail organisations intend to deploy IoT in the next two years. Even though the survey participants ranged across various industries and firm sizes, the paper does not provide a macro view or provide enough evidence to generalise about IoT deployment in Australian retail industry. The report also lacks credibility as the survey objective was to promote Microsoft products. Therefore, methodologically sound empirical evidence on this theme could be of value to the industry as well as to policy makers.

The research report by Roy Morgan (2016) find the value to retailers of properly identifying their customers and the aspiration of consumers to have an increasingly 'frictionless' retail experience. With a proactive approach to customer requisites, retailers can thrive in the digital economy by investing in technology to integrate with IoT devices (Dootson 2018). Industry reports suggest that IoT's potential impact on the Australian economy could reach $120 billion by 2025 (Heydon & Zeichner 2015). The digital disruption of the retail industry is projected to be at one of the highest intensities of all industries by 2020 (Rigby & Tager 2014). Ramoz (2017) report claims that retail is the second highest digitised industry, globally, at 50%, behind media and entertainment. Research by Deloitte signals the rapid growth in digital uptake in Australia, with digital influencing 40% of retail bricks and mortar store visits; 65% of customers using a digital device before shopping and 31% during shopping, using digital devices to research (find, compare) products increasing the conversion of sales by 25%, and overall approximately 21% of consumers believing that digitalisation increases their overall volume of the order (Deloitte Digital Retail 2015).

A survey commissioned by Zebra Technologies reveal that 96 % of Australian retailers are prepared to make changes to bring IoT into their operations (Zebra 2015). However, it has been found that many Australian businesses are not capitalising on the full potential of digital technologies, and, therefore, they may be missing out on productivity benefits of digital maturity (Department of Industry Innovation and Science 2016).

In summary, it has been widely corroborated that "the digital retail revolution is here, and Australian retailers who stick to the old ways of doing things will be left behind" (Ramoz 2017). Within this context, empirical research to verify the link between IoT and SCI process to impact on retail performance may provide stronger evidence of IoT's perceived potency in the industry for academics, practitioners and policy makers alike.

2.10 Chapter summary

This chapter reviewed the background literature at the intersection of supply chain management and Information Systems (IS) literature with the purpose of exploring how ICT implementation has enabled SCI and its effect on supply chain performance. The review also revealed the potential applications of IoT in general, but its implementation within a supply chain integration context was very limited. Furthermore, it reviewed the organisational capability theory that underpins this study in the context of the Australian retail industry.

This literature review has revealed five main themes.

1. Supply chain performance and firm performance are significantly related to each other.
2. SCI is considered to be an important enabler of supply chain performance.
3. ICT is a digital enabler for effective SCI, which, in turn, improves performance.
4. IoT represents a technological advancement of generic ICT with additional capabilities, with objects embedded with sensors and softwares having the potential to collect and communicate data over Internet.
5. IoT as a new and disruptive technology has been the foundation for many innovative applications in logistics and supply chain operations reported to have an extensive effect on SCI processes and to impact on performance.
6. However, the literature has not provided enough empirical evidence on the effect of the IoT capability on SCI impacting on supply chain performance.

Scholars argue that there is a void in the literature on the relationship between IoT deployment in supply chain functions and its performance outcomes (Ben-Daya et al. 2017; Mishra et al. 2016; Verdouw et al. 2016). This literature review has further identified the lack of knowledge on IoT-enabled integration as an organisational capability and its impact on supply chain and firm performance. Therefore, this study presents an empirical examination on whether IoT can strengthen SCI to influence performance in the Australian retail industry, to address this identified knowledge gap.

In summary, IoT is a disruptive ICT innovation that can revolutionise supply chains. Although the effect of ICT is theorised for its effect on SCI to improve performance, the effect of neoteric IoT capability has not been empirically verified. Overall, research on achieving SCI via IoT is not evident in the literature. This study draws upon organisational capability theory to consider IoT as a core capability to achieve dynamic integration capability in supply chains, to impact supply chain performance and in turn firm performance. It addresses the call for empirical evidence to verify the effect of IoT, in addition to traditional ICT, in supply chains for greater performance.

Based on the gaps identified in this chapter, the next chapter develops a conceptual framework to represent IoT-enabled SCI and performance, and presents a series of hypotheses on this relationship, supported by the literature.

Chapter 3
The conceptual framework and hypotheses

3.1 Introduction

Chapter 2 explored the background literature on supply chain management, SCI, ICT and IoT. It identified the attributes of each concept and established the relationship between each as discussed by previous scholars. It was argued that there is a relationship between IoT capability and SCI, impacting supply chain and in turn firm performance. The chapter not only compiled relevant knowledge of each theme and their relationships, but also identified the gaps in the scholarly body of knowledge regarding the performance outcomes of the application of IoT to supply chains in general and its positive effect on SCI specifically, as the important mediation link that enables performance.

The studies have stressed the current role and the potential of IoT capabilities to achieve SCI for performance gains. With the emergence of IoT that can connect anything, anytime, it is timely to uncover whether IoT capabilities can further strengthen SCI for greater performance gains. Although, IoT capability qualify, as an extended ICT capability, no study to date has considered its disruptive effect on SCI. While the researchers have stressed the effect of ICT for SCI, a gap exists in knowledge when it comes to the relationship between IoT and SCI and resulting performance outcomes.

This chapter attempts to explain how IoT, SCI, supply chain performance and firm performance relate in sequence, primarily by drawing on organisational capability theory. Section 3.2 presents the conceptual framework that was adapted from Huo (2012, p. 600) original integration model. Section 3.3 develops hypotheses for this empirical investigation. The chapter concludes with a summary of the conceptual framework and the hypotheses.

The below section reports the theoretical underpinning and the detailed process of hypothesis development.

3.2 The conceptual framework

The literature review in Chapter 2 established that IoT as an extended ICT capability effects SCI and influences supply chain performance and, in turn, firm performance. This section captures this analysis to propose a conceptual framework.

The framework used in this study is built on a central SCI model proposed in a study by Huo (2012, p. 600), which tested the effect of integration on operational and financial performance concurrently from a manufacturing industry perspective. Huo (2012) model, developed from the organisational capability theoretical perspective, focuses on integration from a focal firm perspective examining the three dimensions of internal, supplier and customer integration to test SCI. The multi-dimensional approach is the preferred approach in the literature to better represent the complexity of the SCI construct (Alfalla-Luque et al. 2013), and to gain clear and accurate conclusions (Flynn et al. 2010).

Organisational Capability theory was drawn upon to explain the relationships. Considering ICT as an architectural capability that is embeded in the processes, Huo (2012) does not consider ICT to be a separate construct in his integration study. Rather, ICT capability is seen as a core capability to enable dynamic integration capability for performance gains (Huo 2012; Rai et al. 2006). When testing the effect of digitally enabled SCI on firm performance, Rai et al. (2006), however, drew upon ICT capability as a separate construct, affecting SCI for firm performance. Likewise, adopting Huo (2012) original model, Yu (2015) also considered ICT as a separate construct having an effect on the three dimensions of SCI.

The proposed conceptual framework represents IoT capability as an extension of the generic ICT capability (Borgia 2014) in performing the integration process. While Rai et al. (2006) examined the effect of digitally enabled SCI on firm performance, Li et al. (2009) examined its effect on supply chain performance. Consequently, Qrunfleh and Tarafdar (2014) model represents ICT strategy in supply chains as effecting supply chain performance to influence firm performance. Therefore, the framework is designed to test the hierarchical effect of IoT capability on the three dimensions of SCI, in turn effecting supply chain performance and impacting firm performance. This framework is new, with IoT capability viewed as an extended ICT capability advancing the traditional technology in practice.

First, the framework proposes that IoT capability effects the three dimensions of SCI, namely supplier, internal and customer integration. Second, it proposes that IoT-enabled internal integration influences IoT-enabled external integration. Third, it proposes that the three dimensions of SCI enabled by IoT impact on supply chain performance. Fourth, the framework suggests that IoT-enabled supply chain performance influences firm performance. These six variables form a model to explain how IoT capability effects SCI and the resulting performance outcomes. The framework is designed to represent the influence of the control variables on each construct; however, their influence on performance outcomes will be the primary focus of this thesis. Figure 3.1 represents the proposed conceptual framework for this study. This framework not only integrates supply chain members but also integrates various external and internal logistics actors and service providers performing such roles as transportation, distribution, warehousing and finance.

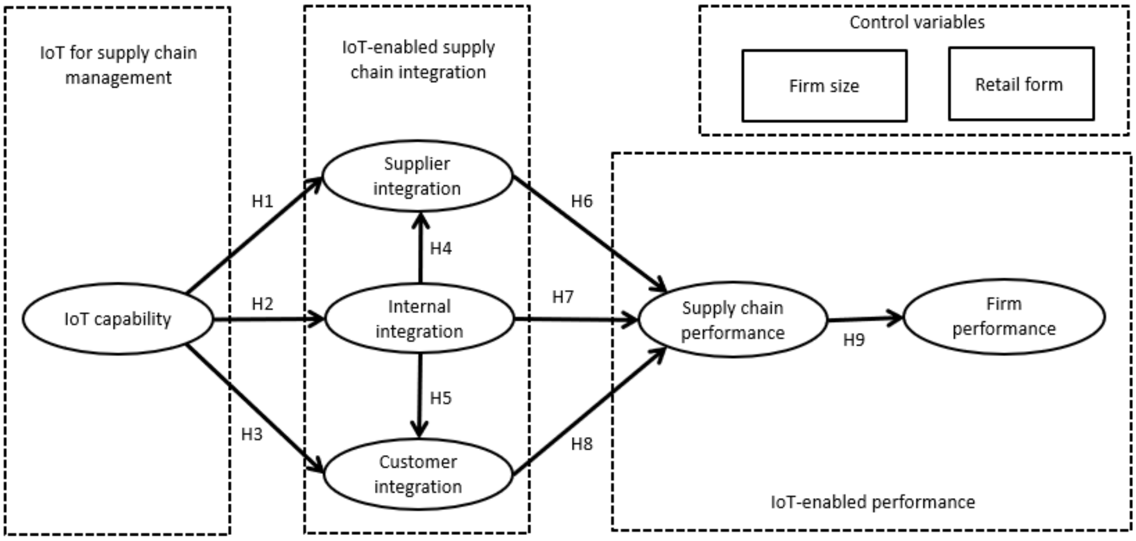


Figure 3.1 Conceptual framework for IoT-enabled SCI and performance

Adapted from Huo (2012, p. 600).

3.3 Hypotheses development

The hypotheses probe the hierarchical relationships between the study constructs represented in the conceptual framework as indicated in Figure 3.1. Nine hypotheses are proposed for this study.

3.3.1 IoT capability and supply chain integration

SCI seeks to achieve cost efficiency and deilvery effectiveness across the entire supply chain, while creating value for the customer (Näslund & Hulthen 2012), via the integration of information, physical, and financial flows between supply chain partners (Rai et al. 2006). Studies find that as a digital enabler, ICT improves SCI via synchronising information flows with physical flows (Kim 2017; Li et al. 2009; Rai et al. 2006; Vanpoucke et al. 2017). ICT facilitates supply chain partners to increase the speed and depth of the information (Vanpoucke et al. 2017), to stimulate information sharing and processing to reinforce intra- and inter-firm collaboration, intensifying SCI (Yu et al. 2016). As a key enabler of SCI, ICT captures, manages and shares critical business processes data across functional areas within a firm boundary and across firms in a supply chain (Yu 2015). Studies have also found that while ICT does not have a direct relationship with performance (Kim 2017; Li et al. 2009), ICT affects performance through its positive effect on SCI. Organisational capability theory also clarifies this relationship to position ICT as a lower order/core capability to effect higher order/dynamic integration capability (Huo 2012; Rai et al. 2006).

The literature reports that IoT, as an extension of ICT (Borgia 2014), also has the extended ability to assist with real-time information flow thereby facilitating inter- and intra-firm communication to furthur integrate supply chains (Ping et al. 2011; Yan et al. 2014). The way Internet connects computers, IoT platform has the capability to potentially connect products, machines and people in sync (Li & Li 2017; Mattern & Floerkemeier 2010), therefore coordinating and integrating the internal and external activities of an enterprise (Cui 2015). IoT, as a latest ICT progression can provide unprecedented intensity of supply chain visibility (Del Giudice 2016), to bridge the divide between physical and virtual worlds, linking the physical flow and the information flow for greater SCI (Ping et al. 2011).

On the context of SCI, scholars argue that examining SCI as a unidimensional construct may obscure vital contributions. Therefore, they advocate that SCI be examined as a multi-dimensional construct (Flynn et al. 2010; Yu 2015). Accordingly, prior studies taking a multidimentional angle, find ICT to be a crucial enabler for all three dimensions of SCI, namely supplier, internal and customer integration (Näslund & Hulthen 2012; Vanpoucke et al. 2017; Yu 2015; Zhang et al. 2011). In the same vein, it is argued that IoT, as a progression of ICT can enhance supplier, internal and customer integration capability.

3.3.1.1 IoT capability and supplier integration

Fundamental to supplier integration is to enable a firm to integrate its supply base (upstream operation) with internal processes and external demand (Ataseven & Nair 2017; Danese & Romano 2011; Flynn, Koufteros & Lu 2016). Supplier integration is defined as "coordination and information sharing with suppliers that provide the focal firm with insights into suppliers' processes, capabilities and constraints, ultimately enabling more effective planning and forecasting, product and process design, and transaction management" (Schoenherr & Swink 2012, p. 100). It is the extent to which a firm collaborates with suppliers to configure inter-firm practices, behaviours, procedures and strategies into synchronised, practicable and cooperative processes to meet customer demand (Huo 2012). Joint planning and broadening the scope of operational, tactical and strategic information sharing with the firm's upstream operation to maximise the value of the entire supply chain are facilitators of supplier integration (Chen & Paulraj 2004; Yu 2015).

Studies have long-established the positive relationships between ICT and supplier integration (Rai et al. 2006; Vanpoucke et al. 2017; Yu 2015; Zhang et al. 2011). Moreover, as per organisational capability theory, ICT as a core capability can positively influence supplier integration (Huo 2012; Rai et al. 2006). ICT implementation help facilitate external integration with suppliers. For example, ERP or EDI enable effective communication between a firm and its suppliers (Vickery et al. 2003; Yu 2015). Likewise, IoT is used for upstream tracking and tracing by connecting supply chain entities to information systems (Chen 2015). It allows firms to have more visibility goods as they move along the supply chain while facilitating advanced quality control and planning (Verdouw et al. 2013; Verdouw et al. 2016). Integrated data collected via IoT devices can be used for strategic planning for product assortments, customisation and postponement (Ng et al. 2015). While IoT promises to offer precious real-time visibility directionally in upstream operations (Ping et al. 2011), its integrated platform can be used for supplier and service provider selection with greater flexibility (Yu et al. 2015). Fleet tracking, shipment condition monitoring, storage conditions of cold chain/perishable products, and product tracking are some other reported functions (Lianguang 2014), thereby integrating suppliers into firms operational processes. Therefore, the hypothesis can be formulated as,

Hypothesis H1: IoT capability has a positive effect on supplier integration.

3.3.1.2 IoT capability and internal integration

Internal integration enables cross-functional collaboration within firm boundaries, such as logistics, operations, finance, sales and marketing operations, to achieve supply chain objectives (Ataseven & Nair 2017; Zhao et al. 2011). Internal integration refers to “the cross-functional intra-firm information sharing and collaboration via synchronised and interconnected systems and processes” (Schoenherr & Swink 2012, p. 100). It is the extent to which a firm structures its behaviours, practices, procedures and strategies into feasible and cooperative, synchronised processes to satisfy customer needs (Flynn et al. 2010; Huo 2012). This synchronised collaborative process between functional departments within a firm facilitate real-time information sharing, operational, tactical and strategic cross-functional collaboration of logistics activities across business functions, in order to improve performance and competitive advantage (Wong et al. 2011a; Yu 2015).

The positive relationships between ICT and internal integration is well established in the literature (Vanpoucke et al. 2017; Yu 2015; Zhang et al. 2011). Organisational capability theory also support the effect of ICT on internal integration (Huo 2012; Rai et al. 2006). Integrated ICT systems facilitate all functional departments (e.g. logistics, manufacturing, sales and marketing, finance, procurement) within a firm to share, access and transmit critical data (Vickery et al. 2003; Yu 2015). Likewise, pervasive smart devices enable smarter decisions, planning and scheduling, more efficient operations due to supply chain visibility based on real-time information (Ben-Daya et al. 2017). Thus, using smart devices, IoT helps data gathering for smart solutions in logistics functions such as inventory flow, remote device management, rotation of shelves and warehouse automated restocking, shelves refilling, fast payment solutions, security and surveillance (Suresh et al. 2014), to strengthen intra-firm processes. Therefore, the hypothesis can be formulated as,

Hypothesis H2: IoT capability has a positive effect on internal integration.

3.3.1.3 IoT capability and customer integration

Customer integration refers to the demand side (downstream) collaboration and coordination activities of a firm (Alfalla-Luque et al. 2013; Ataseven & Nair 2017). Customer integration is defined as "collaborative information sharing efforts with customers that provide strategic insights into market expectations and opportunities to the firm to enable efficient and effective response to customer requirements" (Schoenherr & Swink 2012, p. 100). It is the extent to which a firm integrate customers to structure inter-firm practices, behaviours, procedures and strategies into manageble, synchronised and cooperative processes to satisfy customer requirements (Flynn et al. 2010; Flynn et al. 2016; Huo 2012). Broadening the scope of information sharing and colloboration between the focal firm and its downstream customer to maximise the value of the entire supply chain is the rationale for customer integration (Yu 2015; Zhao et al. 2011).

The literature confirms the relationships between ICT and customer integration (Vanpoucke et al. 2017; Yu 2015; Zhang et al. 2011). As organisational capability theory suggests, ICT is a core capability that can affect customer integration (Huo 2012; Rai et al. 2006). ICT facilitate the external integration with customers in supply chains (Vickery et al. 2003; Yu 2015). The same way, quality-controlled logistics via IoT is reported to allow dynamic and real-time visible, quality control of products, as they move along the supply chain, in delivery to the customer (Ben-Daya et al. 2017). Further, through product delivery process, shop guidance according to a shopping list, customer shopping behaviour and product tracking (Chang et al. 2014), IoT can help customers by integrating them in the supply chain processes. Identifying shopping trends of products that match customer's ideological preferences through smart phone applications (Sánchez-Picot et al. 2014), payment processing based on location/activity duration (Porkodi & Bhuvaneswari 2014), fast payment solutions such as automatically check-out (Fiedler & Meissner 2013) are some of the reported IoT customer integration applications. Therefore, the hypothesis can be formulated as,

Hypothesis H3: IoT capability has a positive effect on customer integration.

3.3.2 IoT-enabled internal integration and external integration

External integration is an extension of internal integration that reaches beyond firm boundaries (Huo 2012). The literature posits that internal integration positively impacts external integration (Huo 2012). Many studies (Ralston et al. 2015; Schoenherr & Swink 2012; Yu et al. 2013; Zhao et al. 2011) have found that the internal integration significantly influences customer and supplier integration externally. This is also confirmed by meta-analyses of literature (Ataseven & Nair 2017; Chang et al. 2016). Intra-firm integration is therefore the foundation for broader integration across the supply chain (Schoenherr & Swink 2012; Simchi-Levi et al. 2008).

Organisational capability theory posits that as a dynamic capability, internal integrative capabilities can directly affect external integrative capabilities (Huo 2012; Zhao et al. 2011). Organisational capability theory also suggests that internal integrative core capabilities such as ICT can directly affect external integrative core capabilities. Therefore, organisations can use internal ICT capability as a foundation to develop external ICT capabilities (Huo 2012). Integration and information exchange with suppliers can improve the understanding of partners' mutual needs to improve joint planning and partnerships (Danese & Romano 2011). The more an organisation invests in ICT infrastructure, the more the likelihood of it achieving integration internally across functional areas increases, in turn strengthening external integration (Yu 2015). Therefore, ICT-enabled internal integrative capabilities can influence a firm's external customers and supplier integrative capabilities (Huo 2012).

3.3.2.1 IoT-enabled internal integration and supplier integration

Internal integration improves suppliers' understanding of the requirements of the focal firm. Furthermore, it can improve information exchange, joint planning, product design and partnerships with suppliers (Huo 2012). Within this context, as an extended ICT capability

(Borgia 2014), the use of internal IoT and improved internal integration can be a base from which to develop IoT capability to integrate suppliers to reinforce SCI. Likewise, the more a firm develops IoT infrastructure, the likelihood of it achieving integration internally across functional areas increases, in turn to strengthen supplier integration (Yu 2015). Therefore, IoT-enabled internal integrative capabilities can influence supplier integrative capabilities (Huo 2012). Integrated IoT systems allow firms to collect, integrate, analyse critical logistics data, for those information to be shared with suppliers to provide real-time visibility in planning and focasting (Ping et al. 2011). Data collected via IoT devices can be shared and the systems can be integrated with suppliers in operational and strategic planning via integration (Ng et al. 2015) to strengthen upstream integration. Therefore, it is hypothesised that,

Hypothesis H4: IoT-enabled internal integration has a positive influence on IoT-enabled supplier integration.

3.3.2.2 IoT-enabled internal integration and customer integration

Where in a dynamic business environment, lacking cooperation of internal functions, it's problematic for firms to collaborate with customers or meet their requirements (Huo 2012). Therefore, internal integration can facilitate firms to better understand the customers' requirements, to work with customers in information exchange (Huo 2012). In this context, as a progression of ICT (Borgia 2014), strengthened internal integration via IoT can be a base to develop customer integration to reinforce SCI. Therefore, while integration internally across functional areas is increased via IoT, this increased integration in turn can strengthen customer integration (Yu 2015). Thus, IoT-enabled internal integrative capabilities can influence customer integrative capabilities (Huo 2012). In delivery operations, real-time track and trace systems is reported to integrate customers into the firm system. Therefore, customers can also track their product as they move along the supply chain (Ben-Daya et al. 2017). Retailers can integrate customers into their IoT platform, so customers are able to use the system for shopping guidance using their smart-phones, while the retailer can identify customer shopping behaviour via collected customer data (Chang et al. 2014). Having technologies in-house to conduct payment processing based on location/activity duration (Porkodi & Bhuvaneswari 2014) or fast payment solutions such as automatically check-out (Fiedler & Meissner 2013), may encourage IoT acceptance and practise by the customer, to strengthen downstream integration. Therefore, it is hypothesised that, *Hypothesis H5: IoT-enabled internal integration has a positive influence on IoT-enabled customer integration.*

3.3.3 IoT-enabled supply chain integration and supply chain performance

From the organisational capability theory perspective, a firm's integration capability is viewed as a dynamic organisational capability that has a direct effect on performance (Huo 2012). The theory suggests that intergation prevents opportunistic behaviours, curtails production and transaction costs and enhances resource obtainability, while facilitating knowledge sharing among supply chain partners, consequently improving the ability to cope with environmental uncertainty (Huo 2012). Literature suggests that partner integration can minimise costs via waste reduction and asset utilisation (Näslund & Hulthen 2012) and also help supply chains to be more flexible, adaptive, reactive and responsive to cope with risks and market uncertainty (Reaidy et al. 2015). Therefore, it is well established that SCI improves supply chain performance (Childerhouse & Towill 2011; Frohlich & Westbrook 2001; Näslund & Hulthen 2012).

ICT capability is also likely to influence performance through quality improvements, enhanced productivity and utilisation, reduced waste and ultimately, increased supply chain efficiency and effectiveness (Jayaram et al. 2010). The studies have found that ICT-enabled SCI or digitally enabled SCI has a positive effect on supply chain performance (Li et al. 2009; Prajogo & Olhager 2012; Vanpoucke et al. 2017). Importantly, it has been confirmed that ICT has no direct effect on performance. Rather, the effect on supply chain performance is via its positive effect on SCI (Li et al. 2009). Organisational capability theory also clarifies this relationship where ICT is posited to improve preformance via its positive effect on dynamic integration capability (Huo 2012; Rai et al. 2006).

As an extended ICT capability, IoT is increasingly adopted to further improve supply chain performance (Borgia 2014; Ford 2014; Leung, Cheung & Chu 2014). IoT can optimise how people and systems interact to coordinate their activities. Analytics can be applied to make improvements and promote best practices for greater performance across the entire supply chain through operational efficiency, safety and security and customer experience (Ben-Daya et al. 2017; Haddud et al. 2017). While enhanced digitalisation reinforces SCI to help to improve performance (Shee et al. 2018; Vanpoucke et al. 2017), the extended capabilities of IoT is reported to minimise costs by optimising supply chain operations and reducing human intervention (Borgia 2014). This optimisation can result in lower energy consumption not only saving costs but also reducing greenhouse gas emissions (Mishra et al. 2016). Further, IoT enhances supply chain flexibility to improve customer satisfaction (Yu et al. 2015). Zara, for instance, achieves planning flexibility, effective replenishment, shorter lead times and product variations with the assistance of such IoT devices (Qrunfleh & Tarafdar 2014). IoT can improve the way people and systems collaborate and coordinate supply chain processes and analyse captured data for better planning (Del Giudice 2016). This helps to identify optimisation prospects and effective procedures for performance gains throughout the entire supply chain via operational efficiency, quality, flexibility, delivery reliability and customer experience (Ben-Daya et al. 2017). The literature suggests that IoT is an enabler of SCI (Chen 2015; Yan et al. 2014). The three dynamics of SCI via IoT, therefore, can be argued for its influence on supply chain performance.

3.3.3.1 IoT-enabled supplier integration and supply chain performance

Prior literature demonstrates that supplier integration improves the operational performance of the focal firm as well as the suppliers to improve supply chain performance (Ataseven & Nair 2017; Frohlich & Westbrook 2001; Schoenherr & Swink 2012). Supplier integration can improve communication performance with suppliers, and affect supply chain and logistics performance (Huo 2012). Likewise, prior studies have confirmed the effect of various facets of ICT-enabled supplier integration on supply chain or operational performance (Shee et al. 2018; Yu 2015; Zhang et al. 2011). Organisational capability theory also suggest that supplier integration strengthened by ICT can improve performance (Huo 2012; Rai et al. 2006). In the same vein, the authors have argued that supplier integration enhanced by IoT can improve supply chain performance (Ben-Daya et al. 2017; Liu & Sun 2011a; Srinivasan et al. 2017; Yu et al. 2015; Zhou & Piramuthu 2015). IoT-enabled supplier integration, therefore, is likely to influence supply chain performance. Hence, the hypotheses can be formulated as,

Hypothesis H6: IoT-enabled supplier integration has a positive influence on supply chain performance.

3.3.3.2 IoT-enabled internal integration and supply chain performance

Internal integration facilitates co-operation between various firm functions to improve delivery and flexibility performance, and customer service. It can also facilitate suppliers' operational performance in serving firms, to effect overall supply chain performance (Huo

2012). The effect of internal integration on supply chain performance is well documented in literature (Alfalla-Luque et al. 2013; Ataseven & Nair 2017; Frohlich & Westbrook 2001). Likewise, prior studies have confirmed the effect of various facets of ICT-enabled supplier integration on supply chain or operational performance (Shee et al. 2018; Yu 2015; Zhang et al. 2011). Organisational capability theory also advocates that internal integration strengthened by ICT can enhance performance (Huo 2012; Rai et al. 2006). The literature conceptualises that internal integration empowered by IoT can improve various aspects of supply chain performance (Balaji & Roy 2017; de Rivera et al. 2014; Liu & Geng 2016; Reaidy et al. 2015; Satapathy et al. 2015). IoT-enabled internal integration, therefore, is likely to influence supply chain performance. Hence, the hypotheses can be formulated as,

Hypothesis H7: IoT-enabled internal integration has a positive influence on supply chain performance.

3.3.3.3 IoT-enabled customer integration and supply chain performance

Closer interactions among firms and their customers enhances information accuracy, and this superior accuracy in customer information can reduce inventory obsolescence with improved inventory planning, to make firms more efficient and responsive to customer requirements (Huo 2012). Many studies have found the impact of customer integration on supply chain or operational performance (Alfalla-Luque et al. 2013; Ataseven & Nair 2017; Frohlich & Westbrook 2001). Organisational capability theory also predicts that customer integration streangthned by ICT can have a posiitve effect on performance (Huo 2012; Rai et al. 2006). Similarly, the authors argue that customer integration facilitated by IoT can improve many dynamics of supply chain performance (Anderseck & Hille 2013; Burke et al. 2013; Chang et al. 2014; Riggins & Wamba 2015). The IoT-enabled customer integration, therefore, is likely to influence supply chain performance. Hence, the hypotheses can be formulated as,

Hypothesis H8: IoT-enabled customer integration has a positive influence on supply chain performance.

3.3.4 IoT-enabled supply chain performance and firm performance

Organisational capability theory refers to how organisational capabilities directly or indirectly affect a firm's capacity to achieve performance outcomes (Huo 2012). The literature advocates the notion that supply chain performance positively effects firm performance (Christopher & Ryals 1999; Simchi-Levi et al. 2008). While supply chain strategy improves performance by focussing on cost, quality, delivery and flexibility improvement (Gunasekaran et al. 2004), it attempts to align with the firm objectives of improving triple bottom line performance to generate environmental, social, and economic benefits (Carter & Rogers 2008; Elkington 1997).

The literature further confirms that ICT-enabled supply chain performance impacts firm performance positively (Qrunfleh & Tarafdar 2014; Vanpoucke et al. 2017). In addition, the literature also suggests that IoT-enabled supply chain performance influences firm performance (Trappey et al. 2017; Zhou et al. 2015b). The real time information provided by IoT helps track supply chain activities, from product design to the end-users, providing accurate and timely information to help organisations respond to market changes (Mishra et al. 2016). These reported performance outcomes are not restricted to operational or financial benefits but also include the firm's sustainable triple bottom lines (Ben-Daya et al. 2017; Borgia 2014). Therefore, IoT-enabled supply chain performance influences firm performance. Hence, the following hypothesis is proposed:

Hypothesis H9: IoT-enabled supply chain performance is positively related to firm performance.

Table 3.1 below summarises the list of hypotheses.

Table 3.1 The list of hypotheses

Hypotheses no	Path	Hypotheses
H1	**IoT capability → Supplier integration**	*IoT capability has a positive effect on supplier integration.*
H2	**IoT capability → Internal integration**	*IoT capability has a positive effect on internal integration.*
H3	**IoT capability → Customer integration**	*IoT capability has a positive effect on customer integration.*
H4	**Internal integration → Supplier integration**	*IoT-enabled internal integration has a positive influnece on IoT-enabled supplier integration.*
H5	**Internal integration → Customer integration**	*IoT-enabled internal integration has a positive influence on IoT-enabled customer integration.*
H6	**Supplier integration → Supply chain performance**	*IoT-enabled supplier integration has a positive influence on supply chain performance.*

H7	**Internal integration → Supply chain performance**	*IoT-enabled internal integration has a positive influence on supply chain performance.*
H8	**Customer integration → Supply chain performance**	*IoT-enabled customer integration has a positive influence on supply chain performance.*
H9	**Supply chain performance → Firm performance**	*IoT-enabled supply chain performance is positively related to firm performance.*

3.3.5 Control variables

Variations in the hypothesised relationships can be better explained when controls are appropriately applied (Dong et al. 2009). The conceptual framework allows control variables to interact without restrictions, therefore we can test their effect from the first construct "IoT capability" and onwards. The influence of the control variables on each construct in the framework can ideally be examined without any issue. However, the influence of control variables on performance outcomes (supply chain performance and firm performance) will be the primary focus to simplify the analysis process. Previous studies have tested the effect of control variables on a single construct, such as performance (Kim & Lee 2010; Rai et al. 2006; Yu et al. 2013). SCI literature has analysed the context using such control variables as firm size, industry sector, firm age, production process characteristics, product seasonality, product perishability and product customisation level (Ataseven & Nair 2017). This study chose two control variables: firm size (number of employees), and the retail form (either bricks and mortar, e-tail or multimodal/omni-channel). First, the study needs to control for firm size, as it often found to determine a firm's actions and performance (Kim & Lee 2010). Firm size has been used as a control variable in many digitally enabled SCI studies (Prajogo & Olhager 2012; Rai et al. 2006). Large size can be a strength to acquire capabilities through resource availability, the economics of scale and the ability to influence supply chain partners (Kim & Lee 2010).

Second, the study includes firms from multiple retail forms. Therefore, the study requires a control for retail form specific effects. In the era of IoT, it is mandatory to link products sold through e-tailers, with a unique identifier to support identification, tracking, monitoring and management (Karakostas 2013). Hence, the influence of IoT on each retail form could vary, as the e-tail model relies more on information sharing for physical goods flows than the bricks and mortar model, especially in the downstream operation (Lee & Whang 2001). On the other hand, IoT's effect on tracking products, product avalability on shelves and understanding customer requirements is very important in brick and mortar operations. Therefore, the retail form in terms of bricks and mortar, e-tail or multimodal/omni-channel characteristics is considered a control.

3.4 Chapter summary

This chapter presented the proposed conceptual framework that represents the hierarchical effect of IoT capability on supplier, internal and customer integration, in turn affecting supply chain performance to impact on firm performance. The literature reports that IoT positively effects SCI. Drawing on the organisational capability theory perspective, it was posited that IoT capability is an extension of the lower order/core ICT capability having an effect on higher order/dynamic integration capability for performance gains. Furthermore, it was proposed that IoT-enabled internal integration positively affects IoT-enabled external integration. To test these propositions, this chapter outlines nine hypotheses based on the conceptual framework.

The next chapter explains the methodology, stipulating the research design, the research instruments applied and the data collection methods, to conduct the empirical examination, by testing the conceptual framework based on the research questions.

Chapter 4
Methodology

4.1 Introduction

The methodology is the general approach situated within a broader research paradigm taken by the researcher in conducting the research project (Leedy & Ormrod 2001). It outlines theory and analysis of how research should proceed (Harding 1987). This chapter outlines the pragmatist research paradigm that was applied in this study. The study is designed as a mixed methods study encompassing quantitative and qualitative Phases. Phase 1 empirically examined the study hypotheses based on a survey questionnaire (n=227) to capture the perspectives of firms representing the Australian retail industry. Phase 2 drew on semi-structured interviews to interpret and validate the survey findings through 13 interviews purposefully sampled from the retail industry firms. The quantitative and qualitative data collected by employing the two methods were used to gain an understanding of the relationships between IoT, SCI, and performances.

The chapter begins with an explanation of the research philosophies that inform this study in section 4.2. Then, the details of the research design methods (section 4.3), instrument development procedures and measurement validation mechanisms for both Phase 1 and Phase 2 are reviewed, in succession. The sections also discuss the sampling procedures for both quantitative and qualitative studies, followed by data analysis techniques applied to reach the study findings. Finally, conclusions are outlined.

4.2 Research Paradigm

The research paradigm is the philosophy that governs the selection of research questions, the learning approach that researchers apply to decipher the research problem and the methods of investigating the selected questions (Morgan 2007, 2014). The four commonly discussed research paradigms are post-positivism, constructivism, transformative and pragmatism. (Creswell 2014; Mertens 2014).

Paradigms consist of ontology, epistemology, and axiology which all inform the methodology (Creswell & Plano Clark 2011). Ontology refers to the nature of reality and whether it exists as a knowable objective truth, independent of the creator of the knowledge (researcher) (Gruber 1993). Two key common ontological assumptions are that (a) reality is out there waiting to be discovered and (b) it is constructed by meaning makers including people or communities that are studied, and by the researcher (Crotty 1998). Epistemology is the study of the nature of knowledge and thought (Jonassen 1991), including what counts as knowledge, what can be known and how it is studied, including criteria for assessing what good or bad knowledge is. It is the epistemological considerations that govern the understanding of the subject (Bryman 2015). Axiology is the domain of values and ethics (Baptiste 2001). It governs to what extent the researcher's values are seen to permeate the research process (Ponterotto 2005).

This study takes a pragmatic stance towards knowledge. The objective of this study is to investigate the relationship between IoT capability and the three dimensions of SCI (i.e. internal integration, supplier integration, and customer integration) and their effect on supply chain performance and, in turn, firm performance. The ontological assumptions in this study consider that IoT capability and SCI processes exist in reality, outside the mind of the researcher and the managers in retail firms. The characteristics of IoT capability, internal integration, supplier integration, customer integration, supply chain performance and firm performance exist in retail supply chains regardless of the researchers' interpretation. However, the knowledge about the influence of IoT capability on SCI that eventually affects supply chain performance and firm performance is captured through the managerial perceptions of retail firms.

Pragmatism embraces both subjective and objective approaches. The pragmatist paradigm can maintain a stance between the objectivity in performance measures and the subjectivity of perceptions (Shannon-Baker 2016). It is orientated towards resolving practical problems in the real world (Feilzer 2010). Pragmatism supports to draw on unanticipated data emerging from the study into the analysis process (Feilzer 2010). It links theory prior and subsequent to the data collection and uses inductive, deductive and abductive thinking (Feilzer 2010; Morgan 2007).

As it advocates the benefits of different approaches to conducting research, pragmatism supports mixed method research designs (Bergman 2010; Creswell 2014; Feilzer 2010; Mertens 2014; Morgan 2007, 2014). A mixed method research design capitalises on the strengths of both qualitative and quantitative approaches and compensates for their weaknesses (Creswell 2014; Creswell & Plano Clark 2011; Soni & Kodali 2012). Mixed methods were employed in this study to capture both a macro overview via a survey of the Australian retail industry and micro in-depth information from interviews to illustrate key themes and generate greater understanding of the survey findings.

The following sections discuss the overall research design, rationalise the choice of each method for addressing the research questions and details the steps adopted in the quantitative and qualitative phases.

4.3 Research design

The mixed methods research design facilitates a combination of research approaches and procedures to help best answer the research questions (Creswell 2014; Flint et al. 2012; Shannon-Baker 2016). There are many rationales for pursuing mixed methods research designs. This includes, expansion (using different methods for different research questions), triangulation (bringing together results from different methods), initiation (reframing the research questions in light of contradictions), complementarity (results of one method extending the results from another method), and development (results from one method sequentially informing the design of another method) (Greene 2007).

Flint et al. (2012) outline how the prevalence of quantitative single-method research design undermines the inherited robustness of supply chain management research as such design is limiting for inquiry into a complex phenomenon. Therefore, to fully understand it, more than one type of research approach is considered crucial. Also, this constraint subjects the research to certain inherent methodological biases. Since all research methods have their own benefits and limitations, mixed-methods research design mends these issues to an extent via the application of both qualitative and quantitative approaches together to generate multiple perspectives on the investigated phenomenon (Flint et al. 2012). Therefore, it offsets the risk of method bias considerably to develop a more realistic and thorough perspective to provide vigorous and robust results (Flint et al. 2012; Singhal et al. 2008). However, mixed methods have rarely been deployed in supply chain management research (Flint et al. 2012).

Out of the mixed methods research designs, this study used the complementarity method. That is employing a secondary method to validate, interpret or support the results obtained applying the primary method. In this study, the primary quantitative phase led the secondary qualitative phase.

This study used two methods to generate data: a survey and interviews. The multiple interviews were used to explain/interpret and confirm/reject the findings of the survey study. The survey instrument was designed, piloted, refined and then deployed to a larger sample. After collecting the survey data, analysing and concluding the findings of the survey, the qualitative data was collected via interviews, which were designed by drawing on the survey results. The data was collected and analysed separately in sequence. The discussion section reports the findings together. In doing so, this pragmatic research design incorporates a post-positivist (survey) and constructionist (interviews, case study) approach to research design (Creswell et al. 2003).

The first phase was the quantitative study. As the proposed research question one seek to verify the hypothesised relationships between the constructs of IoT capability, SCI, and performance, quantitative methods are suitable (Bryman 2015; Hair et al. 2014). The assumption that underpins survey-based quantitative research approach is that it rationalises the relationships between predictors and their outcomes, as to how they exist in a distinct point in time (Saunders 2011). Supply chain management literature has widely used the survey method to examine the relationship between SCI and performance (van der Vaart & van Donk 2008). The second phase was the qualitative study. The qualitative approaches relate to the socially constructed nature of reality and the situational factors that influence the inquiry (Denzin & Lincoln 1994). Qualitative investigation in this study helped elicit insights from the managers who in fact experience the studied phenomena (Patton 2005). The findings helped validate, interpret and support the quantitative results (Flint et al. 2012). Mixed methods research approach applied integrates the findings of the two phases (Flint et al. 2012; Johnson & Onwuegbuzie 2004). The integration of findings was performed at several instances in this study. First of all, the findings of the quantitative phase informed the qualitative phase. Secondly, the qualitative findings helped validate, interpret and support the quantitative findings to report the overall results.

4.3.1 Quantitative phase

The quantitative phase was designed to explore the research question one that seek to verify the relationship between IoT capability and SCI process and performance theorised in the conceptual framework (refer Figure 3.1). A survey questionnaire was prepared and distributed to organisations representing the Australian retail industry. Structural equation modeling (SEM) employing SPSS AMOS 23 software application was used to test the hypothesised relationship among the study constructs (Byrne 2013). The two-step approach in structural equation modeling fist tested the measurement model before testing the structural model (Anderson & Gerbing 1988; Hair et al. 2014; Huo 2012; Yu et al. 2013). The measurement model verified the unidimensionality, consistency and reliability (alpha reliability and composite reliability) of the constructs and structural model verified structural relationship using the variance-covariance approach (Wang et al. 2006; Yu et al. 2013).

For the quantitative analysis, this study draws upon the tools and approaches contained in the widely cited multivariate analysis text by Hair et al. (2014). This text has guided the study design of supply chain research, including Perera (2016). This study draws upon and modifies the application of Hair et al. (2014) by Perera (2016). Specifically, this study uses a similar sequencing of analysis steps deployed by Perera (2016) in conducting structural equation modelling.

4.3.1.1 Data collection method

The survey is mostly recommended for theory testing in general and in operations management due to its generalisation capability (Karlsson 2016). It is the most frequently used research tool in operations management studies (Flynn et al. 1990) and in supply chain management research (Sachan & Datta 2005; Seuring 2008; Soni & Kodali 2012). It has also been the most widespread data collection method for studies that employ statistical analysis (Dillman 2011; Karlsson 2016; Saunders 2011; Soni & Kodali 2012). Thus, there has been a notable growth in survey research in the supply chain and operations management literature (Boyer & Swink 2008; Knoppen et al. 2015), and widely used to investigate the SCI and performance relationship (van der Vaart & van Donk 2008). Prior similar studies (Huo 2012; Li et al. 2009; Rai et al. 2006; Yu 2015) have successfully used a survey method for data collection.

The most frequently used instrument in survey research is the questionnaire (Flynn et al. 1990; Soni & Kodali 2012). A questionnaire contains a series of sequential questions. It can be completed by different agents in the research process - participants, the researcher or a field/research assistant (Bryman 2015; Flynn et al. 1990; Fowler Jr 2013; Sekaran 2006). However, a self-administered questionnaire was the choice of this study as a commonly harnessed method when administered to a large group of target respondents (Couper 2000; Reimers 2014; Zhang 2000).

Online questionnaires are an efficient method for collecting data, with a faster return and fewer reminders (Smith et al. 2013). Therefore, an online questionnaire was used for the convenience of reachability to target respondents (Buchanan & Hvizdak 2009; James & Busher 2015; Roberts & Allen 2015; Wright 2005). Online surveys enable researchers to construct surveys, promptly deliver them to survey participants conveniently, monitor data, synchronously generate results and visualise the outcome (Buchanan & Hvizdak, 2009). Additionally, internet respondents display greater inclination to provide additional information than postal mail respondents (Mehta & Sivadas 1995). The participants can be prompted to complete skipped items and validate answers through the design and programming of online surveys. Easy access to large populations, reduced costs, speed, reduced time, ease of administration, reduced error in data entry and higher flexibility are some of the advantages of an Internet survey. However, coverage error, measurement error, lack of anonymity, sampling error, nonresponse error, computer illiteracy, computer security and non-deliverability are considered disadvantages or the issues that need to be addressed carefully and adequately (Hoonakker & Carayon 2009). Due to the lack of hard copies, the cost of postal surveys was avoided and also made the study more environmentally sustainable.

A well administered online questionnaire with adequate reminders can generate a similar response rate to a postal paper survey (Baruch 1999; Dillman 2011). The reply rate can be approximately doubled by follow-up emails (Kittleson 1997). Guterbock et al. (2000)'s study found higher response rates than for postal surveys for online surveys. Hoonakker and Carayon (2009) literature review also found that well-designed online surveys is capable of generating equal or even better response than postal mail surveys. Smith et al. (2013) discovered that the participant response rate was higher on their online questionnaire than the postal questionnaire. They were returned twice as quickly with half as many reminders. Cook, Heath and Thompson (2000)'s meta-analysis found that pre-contacts, personalised contacts and number of contacts are particularly associated with high response rates.

4.3.1.2 Measurement scale development process

Effective construct measurement practices are the foundation of empirical research and are central to proper assessment of latent variables (Crook et al. 2010; DeVellis 2003; Hair et al. 2014; Netemeyer, Bearden & Sharma 2003; Reynolds et al. 2010). A good measurement theory is crucial in obtaining valid results in SEM (Hair et al. 2014). Hypothesis tests of structural relationships between constructs are valid or reliable only as its measurement model (Hair et al. 2014).

Researchers have the option of choosing from the number of established scales from previous studies. However, when studying a context that does not have a rich history, if there is lack of established scales, the researcher will have to develop new scales or substantially modify an established scale to suit the new context (Hair et al. 2014). Measures that have been previously established by other studies are referred to as referenced measures. However, they are classified as adapted measures if the referenced measure is slightly modified from its original form (Slavec & Drnovsek 2012). A measure that has not been previously used, and developed for the study by reporting the (some or all) steps in scale development procedures is a new measure (Slavec & Drnovsek 2012). The study context made the use of referenced measures impractical. Therefore, most measures for the constructs were adopted from the literature on similar studies. However, since IoT capability is a new phenomenon that has not been tested in a similar framework-based research before, there was lack of established scales. Thus, the measures on IoT capabilities were newly developed applying what literature claims as its capabilities in a supply chain operations. Overall, given the novelty of the study, the research developed new measures and modified measures from its original form to fit the study objectives. Thus, a scale development process was adapted and reported.

The literature on scale development (Bagozzi & Edwards 1998; Churchill 1979; DeVellis 2003; Hinkin 1998; Netemeyer et al. 2003; Nunnally 1978; Pedhazur & Schmelkin 2013) discusses various vital steps in developing new measures. The scale development process for this study was adapted by following the procedures proposed by Churchill (1979), DeVellis (2003) and Slavec and Drnovsek (2012). Churchill (1979) guidelines on scale development are an eight step process consisting of specifying the domain of interest, generating a sample of items, collecting the initial data, purifying the measures and assessing reliability, collecting new data, assessing reliability with new data, assessing construct validity and developing norms. DeVellis (2003) guidelines are not so far from Churchill (1979), but it includes eight steps and the terms are slightly different. An in-depth literature review conducted by Slavec and Drnovsek (2012, p. 43) identified similar ten scale development steps, grouped into three phases. The first phase is theoretical importance and existence of the construct, and the second phase is representativeness and appropriateness of data collection and statistical analysis, and the third phase is statistical evidence of the construct.

The final version of the survey was to be delivered using the online survey software, Qualtrics (VU Research 2015). Therefore, instead of only having measurement items reviewed, the questionnaire and its delivery mode were also included in the testing process. Following DeVellis (2003) and Churchill (1979) guidance to having experts review the initial item pool, as well as a common practice in studies (Flynn et al. 2010; Huo 2012; Yu

2015) to have experts review of the questionnaire. It received a good feedback from experts not only on items but also the questionnaire design, the delivery mode, and validation. The feedback received from the pilot study was incorporated to improve the survey. The ten-step scale development process adopted in this study is displayed in Table 4.1.

Table 4.1 Scale development process

Reliability tests for pilot study	
1.	Identify the study constructs and the conceptual framework
2.	Generate an item pool
3.	Determine the format for measurement
4.	Questionnaire design and online setup
5.	Expert review
6.	Refine the measurement items and the questionnaire
7.	Pilot study, assess reliability, refinement
8.	Sampling and data collection
9.	Assess for uni-dimensionality
10.	Assess for reliability and validity

4.3.1.2.1 Identify the study constructs and the conceptual framework

The purpose of this step was to specify the content domain by specifying the scope and clarifying the study constructs and the conceptual framework (Figure 3.1). Defining what the researcher intends to measure is the first step in building a new measure (DeVellis 2003). Each latent construct in the conceptual framework was identified, and measurement items were assigned to respective latent construct at this stage (Hair et al. 2014). A definition of new constructs should be proposed with an explanation on how they are different from related existing constructs (Nunnally 1978; Slavec & Drnovsek 2012). Specifying the dimensions of new constructs is also important (Haynes, Richard & Kubany 1995). In this case, IoT capability is a new construct that has not been tested earlier in framework-based research. In-depth interdisciplinary literature review which was reported in Chapter 2 helped succeed this step (DeVellis 2003; Hair et al. 2014). The review also included prior attempts to conceptualise or evaluate similar and closely related constructs (Clark & Watson 1995). To ensure that each construct was distinct, the elements of each construct were drawn from the literature and subsequently modified (DeVellis 2016). The theoretical base in Chapter 2 explained the content domain of the conceptual framework (Figure 3.1) and its constructs before the generation of the item pool took place (Netemeyer et al. 2003).

4.3.1.2.2 Generation of item pool

Latent variables (factors) are the theoretical constructs that cannot be observed directly (Byrne 2013). As they are not directly observable, they cannot either be directly measured (Byrne 2013). Therefore, latent variables are explained by measurable indicators (Byrne 2013). The direct measurement of these indicators, therefore, can represent the indirect measurement of its underlying the construct (Byrne 2013).

The conceptual framework of this study has six theoretical constructs in IoT capability, internal integration, supplier integration, customer integration, supply chain performance and firm performance. When selecting measures for constructs, it is better to have multiple indicators to gain a thorough knowledge of the concept (Bryman 2015; Gerbing & Anderson 1988). DeVellis (2003) argues that the over-inclusiveness should be favoured over under-inclusiveness to include a large number of items in the initial item pool.

The established measurement items in the literature were the primary preference to reinforce the reliability and validity of the scales (Churchill 1979; DeVellis 2003). Ideas for items were also captured via an analysis of the popular scientific press, expert interviews, web pages and statements and lectures by practitioners and entrepreneurs (Slavec & Drnovsek 2012). The contextual suitability of the scales was also verified to ensure the stability of the measures (Kalafatis, Sarpong & Sharif 2005).

The items have to be simple, clear, short and attentive of the reading level ease of the survey target population (Slavec & Drnovsek 2012). With the purpose of capturing the central idea of the constructs and assuring clarity of expression, the scale items were precisely worded. Ambiguity, lengthiness, multiple negativity, double-barrelled questions and leading and loaded facets in items were cautiously avoided (Churchill 1979; DeVellis 2003). A few negatively worded (i.e. reduced) items were purposely introduced to prevent mechanical responses and agreement biases (DeVellis 2016; Sekaran 2006).

The originally established items from the literature were slightly reworded but the original meanings were carefully preserved. As no measures for IoT capability were found in literature, new items were developed to suit the research context of IoT deployment in retail supply chains. Adhering to the above-reviewed criterion, a pool of items for each of the six theoretical constructs were developed. The steps followed to generate items for each construct such as IoT capability, internal integration, supplier integration, customer integration, supply chain performance and firm performance is explained below.

Despite ICT capability having been measured in many different studies (Li et al. 2009; Prajogo & Olhager 2012; Rai et al. 2006; Yu 2015), IoT capability has not been measured empirically in academic research as yet. However, conceptual IoT literature have provided enough clue about the emerging technologies. Therefore the measurement scale for IoT capability was self-developed based on its primary abilities of monitor and measure, control and automate, analyse, information sharing and collaboration of supply chain entities, processes and people (Lee & Lee 2015). The ideas for the items were captured by an analysis of the academic literature, scientific press, expert interviews, web pages, consultancy manuscripts and orations by practitioners (Slavec & Drnovsek 2012).

The following ten new IoT capability items were formed via a review of the literature on how IoT's additional capabilities are operationalised in contrast to generic ICT.

1. The concept of a unique identity is fundamental to each IoT device (Atzori et al. 2010; Lee & Lee 2015). The IoT core concept was first established with RFID, where each item had a unique electronic product code (EPC) to identify supply chain commodities (Verdouw et al. 2016). The primary conceptualisation of IoT is all items having an unique ID (Bardaki et al. 2012; GS1 2016; Karakostas 2013; Leung et al. 2014). Therefore "provide individual item level identification" was considered the first measurement item for IoT capability.
2. However, at the same time, many authors have argued for using IoT for unit level identification purposes such as identifying boxes, containers, and product groups (Gnimpieba et al. 2015; Mishra et al. 2016). Therefore "provide unit level (product group/pallet) identification" was added as the measurement item number two for IoT capability to complement the first item.
3. Another key supply chain attribute IoT has that is heavily discussed in the literature is its ability to track and trace supply chain entities (DHL 2015; Gnimpieba et al. 2015; Liu & Sun 2011a). Therefore "monitor, track and trace supply chain entities and people through auto-captured data" was chosen as the third measurement item for IoT capability.
4. IoT's sensory ability to capture and quantify conditions of the supply chain was another key attribute frequently articulated in the literature (DHL 2015; Perera et al. 2015; Thoma et al. 2013), which led to the addition of item four "measure supply chain activities, processes and its environmental conditions".

5. Internet connectivity and being able to access each device via the Internet has allowed to remotely control or actuate such IoT devices (de Rivera et al. 2014; DHL 2015; Mishra et al. 2016; Ruan et al. 2012). Therefore "help control supply chain processes remotely" was chosen as the measurement item five for IoT capability.
6. Literature discuss real-time supply chain visibility as another crucial undisputed capability that IoT has added to the supply chain (de Rivera et al. 2014; DHL 2015; Forrester Consulting 2014; Yan et al. 2014). Therefore "provide real-time information to optimise supply chain activities" was chosen.
7. Real-time streaming analytics was only possible due to IoT technology availability, where IoT data capture and transfer made it possible for analytical programmes to run in real-time to analyse the captured data to make real-time intelligence (DHL 2015; marketsandmarkets 2015; Schlegel 2014; Uckelmann et al. 2011). Therefore, the seventh item chosen to measure IoT capability was "provide real-time intelligence of supply chain operations".
8. IoT's capability to collect additional data flowing in the supply chain is virtually undisputed, therefore "provide large volumes and variety of data to apply data analytics for tactical and strategic decision making" was chosen to represent this potential in providing in-depth data for analysis (Kaivo-oja et al. 2015; Perera et al. 2015; Tsai et al. 2014).
9. Having "anytime" connected devices "anywhere" improves data capture, which in-turn turns into intelligence that can be shared between supply chain operators inter and intra-firm for greater collaboration (Kiritsis 2011; Lee & Lee 2015; Perera et al. 2014). Therefore "to strengthen inter and intra organisational information sharing within the supply chain" was the next item chosen.
10. Having information available on hand in real-time allows films to communicate within and among firms to make faster and well informed decisions (Perera & Vasilakos 2016; PWC 2015; Sánchez-Picot et al. 2014; Yu et al. 2015) Thus, "facilitate inter and intra organisational decision making within the supply chain.

Further, SCI has been studied on its three dimensions like supplier integration, internal integration and customer integration suported by organisational capability theory. The integration measures were primarily adapted from a study by Huo (2012) and Rai et al. (2006) because they have used SCI or ICT-enabled SCI and its impact on performance improvement. Out of the ten supplier integration items used in this study, seven were adapted from Huo (2012) , two items from Rai et al. (2006) and one new item was developed to capture the improvement in receiving process for delivered goods as reported in literature (Chow, Choy & Lee 2007). Out of the ten internal integration items, six were adapted from Huo (2012) study and one from Rai et al. (2006) and three new items were newly developed to capture the focal organisations' improved ability to accurately plan and adopt internal processes in collaboration with cross-functional teams, improve replenishment of shop floor shelves and reduce stock shortages on the shop floor shelves (Liu & Sun 2011a; Satapathy et al. 2015; Vlachos 2014). There are nine customer integration items used in this study. Five were adopted from Huo (2012) study and three from Rai et al. (2006) and one new item was developed to capture the focal organisations' improvement in the check-out/dispatch/delivery process of goods (Vlachos 2014; Yu et al. 2015).

This study has used nine supply chain performance measurement items adapted from a study by Schoenherr and Swink (2012). Supply chain operational dimensions are measured by cost, quality, delivery and flexibility (Ataseven & Nair 2017; Prajogo & Olhager 2012; Schmenner & Swink 1998; Wong, Boon-itt & Wong 2011b). Out of the pool of eleven items adapted for firm performance, six were from Rai et al. (2006) study and one item was adapted from Yu et al. (2013). Those seven were based on the conventional measurement aspects of operational excellence, customer relationships and revenue growth (Rai et al. 2006). However, public pressure on organisations urges them to go beyond the above economic measures and to include social and environmental measures of performance. Consequently, Elkington (1997) Triple Bottom Lines (TBL) of organisational sustainability has emerged as an important performance measure. Environmental performance represents how firms do care for environment in their operations. Social performance measures the firms' attention for society as a whole (Subramanian & Gunasekaran 2015). Therefore, two social measurement items and two environmental measurement items were included (Hubbard 2009). Improving employee health and safety and reducing energy use was adapted from a study by Paulraj (2011), improving employee satisfaction adapted from Dolbier et al. (2005) study and improving return/reuse/recycle adapted from Zhu, Sarkis and Lai (2012) study.

4.3.1.2.3 Determine the format for measurement

A Likert scale was chosen as the preferred scale for measurements. It is a commonly used scale in supply chain management research (Huo 2012). The Likert (1932) scale is a psychometric scale most widely employed in survey questionnaires to scale responses

(Westland 2015). It provides a means to capture the variation that points to an underlying phenomenon (Carifio & Perla 2007). It is an appropriate technique for measuring beliefs, opinions and attitudes (DeVellis 2016). Likert scale is a balanced rating scale with an odd number of categories (Malhotra 2006). Therefore, a salient central neutral point where the observed attribute fits amongst the two extremes of the continuum is present (DeVellis 2016). Following prior similar studies (Flynn et al. 2010; Huo 2012; Prajogo et al. 2016; Yu 2015), a seven-point Likert scale was selected to measure all items with the responses ranging from 1 (strongly disagree) to 7 (strongly agree). It provides a higher range of choices for survey respondents than the five-point Likert scale (Huo 2012). Therefore, it is able to capture a wider range of perceptions of the measurement items. Also, the majority of the adopted scale items in previous studies were initially utilised in seven-point Likert scales. Therefore, it was elected as the most suitable for this study, especially as more complex statistical analysis methods can be deployed with the larger breadth that 7-point scales provide (Sekaran 2006). Most SEM applications over the past fifteen years have been based on Likert-type scale data (Byrne 2013).

4.3.1.2.4 Questionnaire design and online setup

The quality of the survey design is critical in achieving a veracious result (Couper 2000). As the research question one seeks to explore the relationship between IoT, SCI and performance, the questionnaire was designed to capture the perspective of the managers in Australian retail firms, who have the knowledge of supply chain and technology applications. The questionnaire design process followed the guidelines provided in the literature in developing a reliable questionnaire and minimising measurement errors and response biases (Flynn et al. 1990; Fowler Jr 2013; Malhotra 2006; Malhotra, Kim & Patil 2006; Rea & Parker 2012). The questionnaire consisted of sixteen questions placed under three sections, with measurement items representing six constructs and their items in the middle section. Most of the questions were close ended. The open-ended questions were only included to capture atypical technology genres and demographic details.

Question one captured the geographic scope of the respondent's supply chain while question two captured various IoT forms deployed in the respondent's retailing. The measurement items on IoT focus on IoT deployment and the way it helps in data capture and operations in logistics functions. Supplier integration and internal integration questions focused on how each of their logistics functions have improved. Thereafter, the Australian tourism industry questions adopted from Jie Li and Carr (2004) were placed as question seven in the questionnaire as the marker variable. The Lindell and Whitney (2001) marker variable technique was employed to verify any presence of common method bias. The marker variable used was theoretically unrelated to the other dependent variables of the study (Lindell & Whitney 2001; Malhotra et al. 2006). From then on, the measurement questions for study constructs customer integration that questioned the improvement of their customer focussed logistics functions, then their improvement in supply chain performance and firm performance were enquired. In accordance with previous supply chain and operations management studies, the study respondents were requested to evaluate improvement over the past 3 years, relative to the performance of their main competitors (Yu et al. 2013).

The last part of the questionnaire contains demographic information of the respondent. The question on organisational size under the Australian Bureau of Statistics (ABS) classification (ABS Retail industry analysis 2014; ABS_ANZSIC 2013) was placed. The organisations were classified as large (employment of 200+), medium (employment of 20 to less than 200 persons) and small (employment of fewer than 20 persons). Then the retail model or form classified under store-based bricks-and-mortar, e-tail and multi-channel (or omni-channel) was probed (ABS_ANZSIC 2013). Then the retail sector/group/nature of respondent organisations was enquired. ABS classifies retail into 34 subdivisions under the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 with six main groups of motor vehicle and motor vehicle parts retailing (subdivision 39), fuel retailing (subdivision 40), food retailing (subdivision 41), other store-based retailing (subdivision 42) and non-store retailing (subdivision 43) (ABS Retail industry analysis 2014; ABS_ANZSIC 2013). Ten sectors or groups were adopted using the above classifications as a guideline. The question not only captured the breakdown of retail industry sector but also acted as a filter to discard non-retail respondents.

An online questionnaire was designed using Qualtrics survey software. Qualtrics is a leading research tool for online surveys, recommended by Victoria University (VU Research 2015). Qualtrics, a ‘software as service’ corporation based in Utah provides Internet mediation technology to develop the questionnaire items online and deliver the survey (Chapman 2014; Hesse-Biber & Griffin 2013). Such online survey tools enable researchers to conveniently construct surveys, promptly deliver them to survey participants, monitor data, synchronously generate results, visualise the outcome and export the responses to SPSS format (Buchanan & Hvizdak 2009; VU Research 2015). The questionnaire used Likert scale options ranging from 1 (strongly disagree) to 7 (strongly agree) were clarified in wording and were organised in a continuum for all the measurement item statements on study constructs. Providing such clarity improves the respondents' ability to distinguish between scale values (DeVellis 2016). It is recommended to automatically validate online survey input (Hoonakker & Carayon 2009). The validation options provided by Qualtrics such as "force response" and custom validation were applied to ensure the respondents did not progress without answering any questions. JavaScript was applied to create an evident square frame around each radio button panel and for it to disappear when the question was answered. The JavaScript not only marked the boundary of the click sensitive area for each radio button but also highlighted the unanswered panels. This ability to highlight and prompt to complete skipped items and validate answers makes the data quality from online questionnaires better than postal questionnaires (Smith et al. 2013). An indication of survey progress was displayed, and the respondents were allowed to interrupt and then re-enter, by keeping incomplete surveys active for three months (Hoonakker & Carayon 2009). The survey and the technology involved were thoroughly pre-tested, and an email address was made available for the respondents to report problems (Hoonakker & Carayon 2009). The Qualtrics offered option was selected to restrict respondents answering the questionnaire more than once.

The online survey was refined following Dillman (2011) design method guide on Internet surveys. A statement ensuring confidentiality, detailed information about the survey, a statement explaining the contribution and a thank you note were included in the online version (Dillman 2011). Firstly, the online questionnaire was reviewed by the supervisors. Feedback was obtained on the clarity and relevance of the questions, their logical structure and the suitability of the choices of answers. Several improvements were made to the questionnaire as well as its Qualtrics depiction as per their feedback. It was decided to offer a summary of the results as an incentive for respondents who chose to provide an email address (Hoonakker & Carayon 2009).

4.3.1.2.5 Expert review

The measurement items were reviewed via its delivery mode. DeVellis (2003) and Churchill (1979) recommend having experts review the initial item pool. Some studies (Flynn et al. 2010; Huo 2012; Yu 2015) have experts review the questionnaire. By doing so, it was expected to capture expert feedback not only on items but also the questionnaire wording, demographic and qualifying questions, the delivery method and validation techniques employed. However, the primary objective was clearly to evaluate the quality and clarity of the initial measurement item pool (DeVellis 2016; Malhotra et al. 2012). The quality of the item is subjective to its relevance to the construct and its comprehensiveness (DeVellis 2016; Malhotra et al. 2012). The expert review is a way to confirm content validity (DeVellis 2016). The face validity of measures of unobservable constructs can be improved with the help of expert judges (Hardesty & Bearden 2004). Content validity is the extent to which the elements of a measurement instrument that include items, response formats and instructions are representative and relevent to the study construct (Haynes et al. 1995; Slavec & Drnovsek 2012).

The questionnaire was reviewed by knowledge experts. As a panel of scholars, five academics specialising in supply chain management or Information and Communication Technology (ICT) or inter-related disciplines were chosen. As industry experts, five managers were asked to critique the questionnaire for clarity, content validity and appropriateness of questionnaire items to improve the questionnaire. The questionnaire was pre-tested through cognitive interviews (Dillman 2011; García 2011). Cognitive interviews can identify problems respondents may confront in understanding survey instructions and scale items, and in formulating responses (García 2011). Reviewer's opinions on the representativeness of items, length and appearance of the instrument, clarity and wording of items, response formats, clarity of instruction and sequence, were recorded (Slavec & Drnovsek 2012).

4.3.1.2.6 Refine the measurement items and the questionnaire

Based on the content evaluations, minor modifications were made to improve the clarity of survey instrument. The response format, the question sequence, the length and the appearance of the instrument were generally applauded. One key comment was on validation, where few experts felt that the respondents should be given the option not to answer questions and that having option to "force responses" was unethical. Therefore, the online validation was changed to "request response" in which the respondents were prompted if they missed a question, but were still given the option to bypass response, if they wished to.

In addition, two new items for IoT capability were suggested by this pre-testing. These two items were "make autonomous supply chain decisions" and "strengthen communication and coordination between operators".

1. Autonomous decision making via sensory and data collection is discussed in the literature as another attribute that can range from a simple conditional decision such as temperature control to highly analytical decision making such as order generation

(Anderseck & Hille 2013; DHL 2015; Liu & Sun 2011a; Perera et al. 2015; Yan et al. 2014). Therefore, “make autonomous supply chain decisions” was chosen to be appended as measurement item six for IoT capability.

2. Having “anytime” “anywhere” connected devices not only allows additional methods of communication to improve communication, but also allows coordination of supply chain process with well informed decisions made via connected devices (Atzori et al. 2012; DHL 2015; Lee & Lee 2015; Perera & Vasilakos 2016; Suresh et al. 2014). Therefore, the item “strengthen communication and coordination between operators” was introduced.

The resultant measurement scale items is shown in Table 4.2. A survey instrument representing these scale items were used in the pilot study.

Table 4.2 Measurement scale items

Item no	Measurement Item	Source
IoT capability		
Q4_1	To provide individual item level identification.	Newly developed
Q4_2	To provide unit level (product group/pallet) identification.	
Q4_3	To monitor, track and trace supply chain entities and people through auto-captured data.	
Q4_4	To measure supply chain activities, processes and its environmental conditions.	
Q4_5	To help control supply chain processes remotely.	
Q4_6	To make autonomous supply chain decisions.	
Q4_7	To provide real-time information to optimise supply chain activities	
Q4_8	To provide real-time intelligence of supply chain operations.	
Q4_9	To provide large volumes and variety of data to apply data analytics for tactical and strategic decision making.	
Q4_10	To strengthen inter and intra organisational information sharing within the supply chain.	
Q4_11	To facilitate inter and intra organisational decision making within the supply chain.	
Q4_12	To strengthen communication and coordination between operators.	
Supplier integration		
Q5_1	Improve information exchange with our suppliers.	Huo (2012)
Q5_2	Establish a quick ordering of inventory from our suppliers.	
Q5_3	Accurately plan and adopt the procurement process in collaboration with our suppliers.	
Q5_4	Stabilise procurement with our suppliers.	
Q5_5	Share real-time demand forecasts with our suppliers.	
Q5_6	Improve strategic partnerships with our suppliers.	
Q5_7	Help our suppliers improve their processes to better meet our needs.	
Q5_8	Improve the account payable processes for suppliers.	Rai et al. (2006)

Q5_9	Improve the transport/logistics processes for logistics partners to deliver orders just in time.	
Q5_10	Improve our receiving processes for delivered goods.	Newly developed
Internal integration		
Q6_1	Improve the integration of data among internal functions.	Huo (2012)
Q6_2	Improve real-time communication and linkage among all internal functions.	
Q6_3	Accurately plan and adopt internal processes in collaboration with cross functional teams.	Newly developed
Q6_4	Make and adopt demand forecasts in collaboration with cross functional teams.	Rai et al. (2006)
Q6_5	Improve inventory management in collaboration with cross functional teams.	Huo (2012)
Q6_6	Improve real-time searching of the inventory levels.	
Q6_7	Improve real-time searching of logistics-related operating data.	
Q6_8	Employ cross functional teams in process improvement.	
Q6_9	Improve replenishment of shop floor shelves.	Newly developed
Q6_10	Reduce stock outs in the shop floor shelves.	
Customer integration		
Q8_1	Improve the strength of linkages with our customers.	Huo (2012)
Q8_2	Improve regular contacts with our customers.	
Q8_3	Improve communication with our customers on products and promotions.	
Q8_4	Make and adopt demand forecasts with a real-time understanding of market trends.	Rai et al. (2006)
Q8_5	Improve the customer shopping experience/time/ordering/customising processes.	Huo (2012)
Q8_6	Accurately plan and adopt the checkout/dispatch/delivery processes through a better understanding of market trends.	Rai et al. (2006)
Q8_7	Improve the check-out/dispatch/delivery process of goods.	Newly developed
Q8_8	Improve and simplify the payment receivable process from our customers.	Rai et al. (2006)
Q8_9	Improve our customer feedback process.	Huo (2012)
Supply chain performance		
Q9_1	Improve product quality.	Schoenherr and Swink (2012)
Q9_2	Improve supply chain delivery reliability.	
Q9_3	Improve fill rates.	
Q9_4	Improve perfect order fulfilment (deliveries with no errors).	
Q9_5	Improve supply chain flexibility (react to product changes, volume, mix).	
Q9_6	Reduce the cash-to-cash cycle time.	
Q9_7	Reduce the total supply chain management cost.	
Q9_8	Reduce the cost of goods sold.	
Q9_9	Improve value-added productivity (sales per employee).	
Firm performance		
Q10_1	Improve the product delivery cycle time.	Rai et al. (2006)
Q10_2	Improve productivity (e.g. assets, operating costs, labour costs).	
Q10_3	Improve sales of existing products.	
Q10_4	Find new revenue streams (e.g. new products, new markets).	
Q10_5	Building strong and continuous bonds with customers.	
Q10_6	Gaining precise knowledge of customer buying patterns.	
Q10_7	Improve customer satisfaction.	Yu et al. (2013)
Q10_8	Improve employee satisfaction.	Dolbier et al. (2005)

Q10_9	Improve employee health and safety.	Paulraj (2011)
Q10_10	Reduce energy use.	
Q10_11	Improve return/re-use/recycle.	Zhu et al. (2012)

4.3.1.2.7 Pilot study, reliability assessment, refinement

Conducting a pilot study on a smaller sample of the target population it is crucial (Churchill 1979; DeVellis 2016). This mini-study on the target population serves dual purposes (Slavec & Drnovsek 2012). Identifying potential problems with the questionnaire is the number one purpose (Dillman, Smyth & Christian 2014). Testing the reliability of new measures is the second purpose (Netemeyer et al. 2003). Thus, a potential improvement with the survey can be identified before the main survey (Saunders 2011; Slavec & Drnovsek 2012).

The pilot study was conducted with 30 retail industry participants through personal and professional contacts. An email invitation that contained a link to the Qualtrics online survey was sent to pilot study target population. Twelve completed questionnaires were received within the first three days, yet only two more were received for the rest of the week. However, another eleven responses were received in response to email reminders, making a total of twenty-six responses for the pilot study (Dillman et al. 2014; Hoonakker & Carayon 2009). Only seven of these provided feedback via email. Some suggestions were helpful to make minor modifications, but some were not considered as they were contradictory.

The pilot data was tested for construct reliability. Reliability is an indicator of a construct that reflects the quality of scale items under it (Churchill 1979; DeVellis 2016; Kline 2013). By calculating Cronbach's alpha using SPSS 23, internal consistency of the scale items were verified (Cronbach 1951). The results indicated values higher than 0.8 corroborating an excellent level of reliability for all constructs (Bernstein & Nunnally 1994; DeVellis 2016; Hair et al. 2014; Kline 2013; Nunnally 1978). The Cronbach alpha values of the pilot study are are presented in Table 4.3.

Table 4.3 Reliability tests for pilot study

Construct	No. of items	Mean	SD	Cr. Alpha
IoT capability	12	4.557	1.290	0.923
Supplier integration	10	4.703	1.269	0.931
Internal integration	10	4.530	1.379	0.942
Customer integration	9	4.654	1.339	0.929
Supply chain performance	9	4.722	1.424	0.855
Firm performance	11	4.633	1.326	0.876

Note: Cr. Alpha=Cronbach's alpha; SD=Standard déviation

At the early stages of research, lower Cronbach's alpha values are tolerable (Nunnally 1978). However, values less than 0.6 are poor and not acceptable (DeVellis 2016). Given that the Cronbach's alpha values were good at over 0.8, further refinement was not required. The survey instrument was considered to be reliable.

4.3.1.2.8 Sampling and data collection: The survey

The litereture does not provide any established rule regarding the sample size (Slavec & Drnovsek 2012). Nonetheless, a minimum sample of 200 responses is recommended to undertake factor analysis (Hinkin 1998). However, Soni and Kodali (2012) find that 63.29 % of 316 research papers on supply chain management published between 1994 and 2009 were based on a sample size less than 200.

The finalised survey instrument was employed to the main survey. A three-step process that included survey population and sampling frame design, survey informant selection, and questionnaire distribution and response collection was followed.

4.3.1.2.8.1 Survey population and sampling frame design

Invited study participants were sampled from the Australian retail organisations representing both traditional bricks-and-mortar retailers and online retailers. The study was exclusively on retail organisations based and operated in Australia, and no offshore retailers were considered. A sampling frame is the representative elements drawn from a population (Neuman 2011; Särndal, Swensson & Wretman 2003). The sampling frame was mainly captured from three different sources. They were public databases, industry associations and snowballing through professional contacts using social media.

Under ABS Australian and New Zealand Standard Industrial Classification (ANZSIC) classification (ABS Retail industry analysis 2014; ABS_ANZSIC 2013), retail businesses are classified to motor vehicle and motor vehicle parts retailing (subdivision 39), fuel retailing (subdivision 40), food retailing (subdivision 41), other store-based retailing (subdivision 42) and non-store retailing (subdivision 43). However, over half (53.9% or 685,883) of the employment is in other store-based retailing (ABS Retail industry analysis 2014). Therefore, the subdivision 42 classification was further granulated for clarity. The granulated sectors of retail organisations derived from the ANZSIC classification are shown in Table 4.4. Organisations under those sectors practising in retail forms of store-based bricks-and-mortar, e-tail (subdivision 43) and multi-channel retailing were identified as the best representations, or sampling frame, for Australian retail firms, and therefore were selected for the survey.

Table 4.4 The categories of retail organisations

Retail category	Subdivision
Restaurant, café, takeaway	Subdivision 41
Supermarkets, grocery	Subdivision 42
Household goods (e.g. hardware, furniture)	Subdivision 42
Clothing, footwear and personal accessories	Subdivision 42
Electrical, electronic, computer	Subdivision 42
Pharmaceutical, cosmetic, toiletry	Subdivision 42
Motor vehicles & parts	Subdivision 39
Fuel and convenience stores	Subdivision 40
Department stores	Subdivision 42
Other	Subdivision 42

A sample of respondents was assembled using the stratified random sampling method. The random sampling method is where all members of the sampling frame having the same chance of being selected and is the most common surveys sampling method (Dillman et al. 2014). Stratified random sampling allows subgroups to be studied in greater detail since stratification usually results in a smaller variance than that given by simple random sampling (Ghosh 1958; Marshall 1996). The objective was to have the sample reasonably represent all subdivisions and categories of retail.

The sample size is important as small sample sizes causes around 30% of statistical conclusion errors of the survey studies in operations management (Malhotra & Grover 1998). Although a sample size of above 35 is considered suitable for statistical analysis, multivariate analysis techniques such as Structural Equation Modeling (SEM) need at least 200 cases or a responses to variables ratio of 10:1 (Soni & Kodali 2012). As SEM was chosen as the key method for data analysis, SEM requirements were the key determinants of the sample size. Anderson and Gerbing (1984) recommend a sample with a minimum of 150 cases to reach an accurate result in SEM. (Hair et al. 2014). While Hair et al. (2014) agree with 150 cases as the recommended minimum for SEM on frameworks consist of seven or fewer constructs, they states that a sample of over 200 cases is more appropriate. If the data deviates from multivariate normality, 15 cases for each construct is suited (Hair et al. 2014). Soni and Kodali (2012) point out that the researcher should not only use a larger sample size but also make an effort to achieve a high response rate.

Tanner (1999) suggests help from industry associations as a strategy to increase responses from organisations. Therefore, to receive over 200 usable responses at 10% response rate, a survey sample of around 2000 from an industry association mailing list was identified. Around a 10% response rate is considered as the minimum accepted response rate in supply chain management research (Kim & Lee 2010).

However, it is documented that survey response rates over recent decades have been in decline (Peytchev, Massey & Tourangeau 2013). Web surveys have been generating relatively low level response rates (Shih & Fan 2008). Also, surveys conducted in impersonal communication, such as posting on mailing lists, have generally produced relatively low response rates (Zhang 2000). More importantly, meagre response rates are common in surveys that target members of professional societies (van der Vaart & van Donk 2008). Therefore, a low response rate was anticipated via the preliminary sampling frame. Hence, a contingency plan was always in place.

The second strategy was to use various online lists of retail companies and the retail section of the Yellow Pages (2016) Australian businesses directory was referred to collect a representative sample (Flynn et al. 2010; Yu 2015; Zhao et al. 2011). The retail organisations were randomly chosen and alphabetically listed to avoid duplication of cases (Flynn et al. 2010; Yu 2015; Zhao et al. 2011). They represented all six states in Australia: New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia. The sample represented all sectors of retail. A single key informant from each randomly selected retailer was identified with the help of LinkedIn professional networking connections and other social media, as prior research has successfully applied a similar method in collecting research data using questionnaire surveys (Baltar & Brunet Icart 2011, 2012). The help of professional and academic connections has been found to be successful in collecting research data using questionnaire survey before (Yu 2015; Yu et al. 2013; Zhao et al. 2011). The use of social networking sites of informants was effective for identifying this ""hard-to-involve"/hard-to-reach" population. To increase the representativeness and sample size, social networking sites can help identify potential respondents with barriers to access (Baltar & Brunet Icart 2011, 2012; Browne 2005). The sample was snowballed from initial connections to the second tier and third tier connections to identify possible respondents belonged to the generated representative sample. Sampling procedures such as snowballing and other chain-referral samples introduce biases (Heckathorn 1997). The snowballing method to identify informants generates non-probabilistic samples (Frank & Snijders 1994; Goodman 1961). However, unlike using the snowballing method to identify informants, this method only used the snowballing of connections to identify respondents from a randomly selected representative sample (Frank & Snijders 1994; Goodman 1961). Therefore, the sample was still probabilistic.

The initial representative sample consisted of potential informants from 589 unique retail organisations. They were pre-contacted electronically, addressed by their name, explained the reason for contact and invited to participate in the survey (Cook et al. 2000; Dillman 2011; Hoonakker & Carayon 2009). The purpose of the study and the potential contribution was explained. Pre-contacting the representative sample created an awareness of the upcoming survey, provided insights on why they may not respond and helped address certain issues related to low response rate. All attempts were made to reach a higher number of contacts (Cook et al. 2000). Out of those contacted, 546 agreed to participate in the survey. Thus, a concluding representative sample of 546 cases was listed by the retail firm name, retail category, informant name, informants' job title, informants email address or communication mode and the phone numbers of some who were happy to pass it on.

4.3.1.2.8.2 Survey informant selection

A single key informant with technology-enabled supply chain knowledge from each retail organisation was recruited for this study. Many previous studies on SCI (Chiang et al. 2014; Flynn et al. 2010; Huo 2012; Zhao et al. 2011) have used single informant approach. Likewise, the studies examining the relationship between SCI and information and communication technology (ICT) (Li et al. 2009; Rai et al. 2006; Yu 2015) have also used single informant. Key informants such as managers having knowledge about overall technology-enabled supply chain practices in their organisations are more likely to provide accurate information. People with job titles such as CEO, director, general manager, operations manager, supply chain manager and IT manager were identified as potential participants. Potential respondents who had been in the focal retail firm for over two years were mainly pursued to ensure their knowledge about the studied themes. Therefore, it is reasonable to presume that the identified informants were able provide reflective opinions about operational performance and be knowledgeable about the use of IoT in logistics operations.

4.3.1.3 Questionnaire distribution and data collection

4.3.1.3.1 Questionnaire distribution: the first attempt

The online questionnaire was first digitally distributed to a sample of around 2000 from an identified industry association mailing list. The group e-mail invitation/recruitment flier (Appendix D) with a weblink to the online questionnaire was sent to the mailing list of the target respondents accompanied by the information sheet (Appendix B) along with the consent information (Appendix E). In order to gain respondents' attention and inspire them to open the e-mail, the subject line of the e-mail is considered to be extremely important, and encourages participation (Hoonakker & Carayon 2009). After much deliberation, the e-mail subject line was set as "The effect of Internet of Things (IoT) on supply chain performance in the Australian Retail Industry". Since the email was sent to a supply chain industry association mailing list, the email stipulated that only the managers in the retail industry should follow through.

The questionnaire (Appendix F) was distributed in accordance with the conduct of responsible research (Buchanan & Hvizdak 2009; Frankel & Siang 1999; James & Busher 2015; Roberts & Allen 2015; Varnhagen et al. 2005). Following prior similar studies (Dillman et al. 2014; Flynn et al. 2010; Hoonakker & Carayon 2009; Yu 2015; Zhao et al. 2011), a number of methods were used to minimise response bias and maximise the response rate. Participants were advised of the research procedures, associated risks, potential benefits of the outcome, their right to decline or withdraw, confidentiality parameters, incentives and the contact detail of the researchers (Varnhagen et al. 2005). Participation in the research was voluntary (Whiteman 2012). Anonymity and confidentiality all through the process were assured (Beddows 2008; Frankel & Siang 1999). To improve the response rate, as an incentive to encourage participation, a summary report of the responses was promised to those who provided their email address (Couper 2000; Hoonakker & Carayon 2009; Yu 2015; Zhang 2000). Follow-up reminder emails were sent after two weeks to further encourage completion and return of the questionnaires (Dillman et al. 2014; Flynn et al. 1990; Hoonakker & Carayon 2009; Kittleson 1997).

4.3.1.3.2 Response collection: the first attempt

After the distribution of the online questionnaire to around 2000 potential respondents from an identified industry association mailing list, only four questionnaires were returned after two weeks. Three more were received after the reminders. The response rate was less than 1 %. Out of a total of seven respondents, only four were from the retail industry. The mailing list could not filter-out non-retails (i.e. 3PLs, manufacturers) or restrict the email invitation to a single potential participant of each retail firm. Due to the low response rate, it was decided to look for an alternative method of data collection. The responses were discarded as the outcome would have negatively influenced the study response rate if combined with the outcome of the substitute method.

4.3.1.3.3 Questionnaire distribution: The second attempt

Due to the low response rate in the initial attempt, the secondary strategy of sending the questionnaire to the randomly selected informants via businesses directories was executed. The survey was administered to the pre-contacted key informants of the final representative sample of 546 cases, by following the same methodological approach outlined in the first data collection attempt. This time, however, the respondents were approached personally (Cook et al. 2000; Dillman 2011; Hoonakker & Carayon 2009).

4.3.1.3.4 Response collection: the second attempt

Within the first two weeks, 93 questionnaires were completed. After sending email reminders, 78 more responses were received, making it a total of 171 responses within a month. There were however 37 incomplete questionnaires in the system. After a month, a follow-up phone call was made to all informants in the final representative sample, reminding them of the survey and appreciating those who already responded. The three key reasons for no-nresponse were that they were too busy, they forgot about it, and they do not use IoT. It was an opportunity to answer some of their questions and make clarifications. Nevertheless, a final reminder email was sent to each who consented to participate in the survey. The follow up resulted in further 70 responses making a final total of 231 complete responses after two months. The response rate was very healthy 42 % (Flynn et al. 1990). The rigorous process of compilation of the final representative sample and collecting data lasted over eight months, finally completing at end 2016.

4.3.1.3.5 Non-response bias

Non-response bias tests were carried out to test the significant differences between the survey respondents and the non-respondents (Mentzer & Flint 1997). An inspection of any significant variances between the early and late waves of survey responses is a method of testing non-respondent bias (Armstrong & Overton 1977). Armstrong and Overton (1977) find that the late respondents can be compared to non-respondents. To predict non-response bias, we can assume that the late respondents have a higher likelihood of representing those who did not respond (Armstrong & Overton 1977).

Accordingly, by comparing the demographic variables of early and late respondents at a 60% to 40% split via an independent sample t-test analysis, non-response bias was tested (Huo 2012; Qrunfleh & Tarafdar 2014; Yu 2015). The results did not indicate any significant differences between the early and late responses among the demographic variables at $p < 0.05$, disproving any non-response bias.

4.3.1.4 Quantitative data analysis

At this stage descriptive statistical analysis is performed and statistical evidence of the study constructs are presented. The data analysis software primarily used in this study were SPSS 23 and SPSS AMOS 23 packages with some help of Microsoft Excel. Structural equation modeling (SEM) using SPSS AMOS 23 was applied to investigate the acceptability of the theoretical model by testing the relationship between study variables (Byrne 2013; Hair et al. 2014; Hu & Bentler 1999). Prior to conducting statistical analysis, the data set was preliminarily screened and purified. At this stage, any inadequate responses were removed, missing values were analysed and instated, and distribution normality was tested. Anderson and Gerbing (1988) two-step approach to SEM proposes testing the measurement model followed by the structural model (Huo 2012; Yu et al. 2013). This two-step approach to model testing is a widely accepted method (Hair et al. 2010). The measurement model verified the uni-dimensionality, reliability (alpha reliability and composite reliability) and consistency of the constructs, and the structural model verified the structural relationship using variance-covariance approach (Hair et al. 2014; Wang et al. 2006; Yu et al. 2013). This section imparts the details of the stage by stage procedures followed in the statistical analysis stage.

4.3.1.4.1 Preliminary analysis

The objective of this stage was to transform the raw data that was collected from the survey into a suitable format to conduct multivariate statistical analysis (Hair et al. 2014). The process included a screening of the data, treating for missing values and testing for distribution normality and outliers.

4.3.1.4.1.1 Data screening

Data screening process ensures that the data set is 'clean' (free from omissions or errors) and fit to proceed for further statistical analyses (Field 2013). Therefore, it is considered as an important step before SEM analysis. Tabachnick and Fidel (2013) outline a standard process for data screening.

When the survey was finalised, the responses collected by Qualtrics were exported to SPSS. The Qualtrics exported items representing numerical codes as per the Likert scale while unanswered responses were left blank. First of all, the IP addressed were removed, the optional personal detail that was provided such as e-mail addresses were detached before analysis and each questionnaire response was assigned a case number. Each case was assessed for its suitability to proceed for analysis.

Although the questionnaire was exclusively sent to the managers of the retail industry, the data was screened to confirm that all the responses still complied with the unit of analysis of this study, which was a single respondent from an organisation from the retail industry. Question 13 on the category of retail industry and question 12 on the retail form were used as the screening questions for this purpose. The non-retail industry respondents cannot fit themselves into one of the categories, therefore they have to pick "Other" and explain what they represent. By screening the "Other" categories of the two questions, unsuitable respondents who do not represent the Australian retail industry were removed.

The next step was to confirm that no questionnaires were either answered invariably (ticking the same answer for all the items in questions 6 to 10) or mechanically (in a pattern). First, a visual screening was conducted to identify such cases to be removed. Thereafter, the standard deviations of the measurement items of each questionnaire were tested to inspect any possible invariability further. The cases with the standard deviation of less than 0.5 were candidates for closer examination for invariability, to consider discard as unengaged responses.

4.3.1.4.1.2 Missing value analysis and treatment

Missing data creates major problems for the estimations in SEM (Allison 2003; Hair et al. 2014). Therefore, the treatment of missing values before conducting statistical analysis is necessary (Hair et al. 2014; Little & Rubin 2014). Under 10% of missing data for an individual case can generally be accepted and proceeded to missing value treatment, except a case where the missing data take place on a specific non-random pattern (Hair et al. 2014; Malhotra 1987).

Once it is verified whether the missing values are missing completely at random (MCAR) or missing at random (MAR) patterns, a suitable missing value treatment method or the imputation method can be determined (Allison 2003; Hair et al. 2014). Under the MCAR situations, missing values are entirely unrelated to other variables in the sample (Baraldi & Enders 2010). However, under MAR conditions, missingness is interrelated to other measured variables in the sample, but not to the underlying values of the incomplete variable (Baraldi & Enders 2010).

Little (1988) test for missing completely at random (MCAR) can confirm that the missing data is at completely random, if the MCAR is non-significant ($p > 0.05$) value. What Non-significant MCAR missing values imply is that the observed pattern does not significantly vary from the missing random pattern. Hence, in missing data completely at random patterns, no potential biases can exist (Allison 2003). However, MCAR is often unrealistic in practice (Muthén, Kaplan & Hollis 1987; Raghunathan 2004).

Contrary to MCAR, no statistical test is available to directly test MAR (Baraldi & Enders 2010; Potthoff et al. 2006). Nevertheless, a situation of MAR can be supposed by a significant Little's MCAR value and in addition, if the missingness is predicted from variables apart from the dependent variables in separate variance t-test (Tabachnick & Fidel 2013). Similarly, if the t-test indicates that the missingness is related to dependent variables, the condition of missing not at random (MNAR) is assumed (Tabachnick & Fidel 2013).

These missing cases can be deleted if the missingness is concentrated in a small subset of variables or if the missing values are highly correlated with other complete variables (Hair et al. 2014). In that case, methods such as listwise deletion or pairwise deletion can be used. Listwise deletion is unfitting for small samples as it removes entire cases with missing values, thus further reducing the existing data and the generalisability to the population (Allison 2003). However, incomplete cases are only removed on an analysis-by-analysis basis under pairwise deletion (Baraldi & Enders 2010). Both list-wise and pair-wise deletions are likely to generate biased estimates, if the missingness of the data is incoherent to MCAR (Allison 2003; Baraldi & Enders 2010).

However, there are many imputation methods available to replace missing values including multiple imputations (MI), arithmetical methods such as mean substitution or regression, or model-based methods such as expectation maximisation (EM) (Hair et al. 2014). EM estimation technique is Maximum Likelihood (ML)-based (Allison 2003). ML-based estimation techniques provide unbiased results in MCAR or MAR situations (Allison 2003; Baraldi & Enders 2010; Muthén et al. 1987).

4.3.1.4.1.3 Distribution normality and outliers

Normality is a fundamental assumption applied in multivariate analysis (Hair et al. 2014). It refers to the shape of the data distribution as it corresponds to a normal distribution. All resultant statistical test are likely to be invalid, in case there is a considerable variant from the normal distribution (Hair et al. 2014). Maximum Likelihood (ML) method, the most widely used method for estimating SEMs assumes multivariate normality (Allison 2003).

The uni-variate normality of each variable was examined before progressing to multi-variate normality tests as uni-variate normality is a prerequisite for multi-variate normality (Hair et al. 2014). However, uni-variate normality does not ensure multi-variate normality. The uni-variate normality for each item was verified by using histograms to observe the shape of distribution curves for each item along with skewness and kurtosis estimates. The skewness of less than 3 and kurtosis of less than 10 can be considered for uni-variate normality (Kline 2015).

Subsequent to verifying the uni-variate normality of each item, Mardia's coefficient of multi-variate kurtosis was examined for multi-variate normality. Normalised coefficients greater than 3 reflect non-normality (Mardia 1970, 1974).

The data set was then examined for outliers – bundles of unique combinations of characteristics in an observation point in the dataset that are clearly different from other observations (Hair et al. 2014). These outliers were examined with the use of Mahalanobis distance which indicates the distance of each case in a multi-dimensional space from the intersection of the means of all observations in a single value (Hair et al. 2014; Tabachnick & Fidel 2013). The suggested conservative levels of significance for Mahalanobis distance is at $p = 0.001$ or p=0.005 (Hair et al. 2014). The outlier should be retained unless they are truly uncharacteristic, as removing outliers limits the generalisability of the study (Hair et al. 2014).

4.3.1.4.2 Statistical analysis

Once the preliminary analysis confirmed the suitability of the data to conduct multivariate statistical analysis, the analysis procedures for SEM were applied to test the proposed conceptual framework. As per the two-step approach for model testing for SEM, the measurement model was tested first before testing the structural model (Anderson & Gerbing 1988; Hair et al. 2014).

The measurement model specifies the indicators for each construct or, in other words, specifies the rules of correspondences between manifest variables (items) and latent variables (constructs) (Hair et al. 2014). The connection between factors and their measured variables is its singular focus (Byrne 2013). The structural model represents these links and the causal direction between latent variables (factors) (Byrne 2013).

Maximum Likelihood (ML), the most widely used method in SEM was applied to test the measurement models and the structural model (Allison 2003). Although the ML method conducts estimates assuming multi-variate normality of the data, the outcomes are relatively unbiased if the data is moderately non-normal (Bollen 1989).

The final data set decided on after the preliminary analysis was used for both exploratory factor analysis (EFA) as well as confirmatory factor analysis (CFA) (Huo 2012; Yu 2015). Dimensionality can be accessed via EFA or CFA, or both (Slavec & Drnovsek 2012). If the manifest variables calculate one solitary underlying factor, homogeneity is implied (Clark & Watson 1995). A uni-dimensional measure has only a single dimension, implying its manifest variables underlie a single factor (Netemeyer et al. 2003).

4.3.1.4.2.1 Exploratory factor analysis

EFA is generally performed in the early stages of scale development (Slavec & Drnovsek 2012). The assumption is that the researcher only possesses a limited idea in relation to the dimensionality of the new measure (Netemeyer et al. 2003). When adopting a valid and reliable measurement scale from the existing literature, conducting an EFA is not essential (Hair et al. 2014; Netemeyer et al. 2003). However, in this case, the established measurement scales were applied to a different industry context than what they were designed for in the literature. Also, some of the measurement items, including all the elements for IoT capability, were newly designed, and the established scales were adapted to suit the study objectives. Therefore, it was decided to apply EFA (Byrne 2013; Hair et al. 2014). As the six factors (constructs/ latent variables) representing the conceptual framework of this study were determined to be IoT capability, internal integration, supplier integration, customer integration, supply chain performance and firm performance, the EFA was used to confirm the loadings of their measurement items on the respective constructs.

Prior to proceeding, the data set was evaluated of its sufficiency for EFA, as the nature of the data governs the sample adequacy (Osborne & Costello 2009). Subjective to the strength of the data, even small samples can provide accurate results (Osborne & Costello 2009). Strong data should contain items exhibiting above 0.8 communalities (high communalities) and 0.5 factor loadings (high factor loadings), while not holding items with 0.32 or more factor loadings on two or more factors (no cross-loading) (Osborne & Costello 2009). As it is hard to satisfy the above criteria, the variable-to-subject ratio was practised to estimate the sample size. To minimise the possibility of over-fitting the data, a higher sample ratio per variable was used (Osborne & Costello 2009). Kline (2013) proposed ratio of 2:1 for a sample of minimum 100 cases was finally used as the bottom benchmark to establish the tolerable sample size to perform EFA. The sampling adequacy was later verified by applying Kaiser-Meyer-Olkin (KMO) test (Hair et al. 2014). Kaiser (1974) states that a KMO value of 0.6 or over indicates the factor structure is acceptable for analysis.

Thereafter, Bartlett's test of sphericity was applied to justify that there are sufficient correlations in the data matrix for factor analysis. Correspondingly, if a considerable number of correlations fall below 0.3 or if the partial correlations exceed 0.7, factor analysis is unsuitable (Hair et al. 2014; Tabachnick & Fidel 2013). The anti-image matrices were used to examine partial correlations (Hair et al. 2014).

An EFA was conducted with the data set by selecting principal axis factoring (PAF) for factor extraction method and in addition, direct oblimin oblique rotation as the rotation method (Hair et al. 2014). The oblique rotation method was chosen because, in factor extraction, it takes the correlation of factors into account (Hair et al. 2014).

The retained factors was determined using most commonly used eigenvalue criteria, the Kaiser (1974) criterion, which asserts the factors to be retained if their eigenvalues are greater than one (Beavers et al. 2013). Despite its popularity, Kaiser criterion has been criticised for not being precise in selecting the number of factors (Kline 2013). Therefore, the outcome of the Kaiser criterion was further verified using scree plots. A scree plot graphs the eigenvalues of the number of factors that can be used to find the clear point where the graph bends or breaks to flatten the curve. The number of factors to be retained is suggested by the indicated number of data points above the break (Osborne & Costello 2009). If a single factor is generated with an eigenvalue greater than one and a single data point above the break in the scree plot is displayed, the unidimensionality of the factor is established.

If the factor analysis identified above one factor, the factor loading of each item was inspected using the pattern matrix, where it assists to observe the factor structure in the oblique rotation (Osborne & Costello 2009). The items with factor loadings of over 0.3 better represent the factor structure (Osborne & Costello 2009). Hair et al. (2014) also articulate that minimally acceptable factor loadings is 0.3 and recommends greater values than 0.5 for practical significant. The items loaded into multiple factors with over 0.3 factor loadings (cross-loaded items) were removed (Hair et al. 2014; Osborne & Costello 2009). However, an effort was made to avoid forming factors that measured by below three items, as they do not properly illustrate the data structure (Osborne & Costello 2009).

The EFA determined the manifest variables which represent the latent variables (Hair et al. 2014). The communalities were used to verify the results. Communality is the accounted degree of variation by the factor solution for each variable (Hair et al. 2014). In comparison to the total variance of all factor items, low communality indicates a low shared variance of the item. Hair et al. (2014) recommend a communality value of over 0.5 for an item to be retained. The value of 0.3 was considered as the minimum level, subjective to confirmatory factor analysis (CFA). However, lesser values closer to 0.3 were considered for retention if justified by theory (Kline 2013).

4.3.1.4.2.2 Confirmatory factor analysis

The outcome of the EFA was then subjected to confirmatory factor analysis (CFA) to verify its factorial validity (Byrne 2013; Huo 2012; Yu 2015). How well the constructs are represented by measured variables is examined by CFA (Hair et al. 2014). Therefore, CFA is used to confirm the relationship between observed variables and their underlying factors (Byrne 2013). In CFA, the factor structure, the number of factors and the relationship between factors are previously set (Slavec & Drnovsek 2012). Whether the hypothesised factor model fits the data is measured in analysis (Netemeyer et al. 2003). CFA takes measurement items and factors together into account with path analysis to test the hypothesis (Byrne 2013; Hair et al. 2014). The distinction to EFA is that CFA is suitable when some knowledge of underline latent variable structure is arrived at via empirical research or theory (Byrne 2013).

The measurement models were confirmed in two stages via application of CFA. The first step was testing all six distinct latent variables simultaneous to EFA, and then the full model that represents the links among the latent variables. The one-factor measurement model is identified as a congeneric model while the full model is referred to as the complete CFA model (Byrne 2013; Millsap & Everson 1991). The measurement model confirmed the manner in which the manifest variables represent the latent variables and the relationships between latent variables (Byrne 2013). CFA models were evaluated using goodness of fit (GOF) statistical means to ensure the model fit (Byrne 2013).

4.3.1.4.2.3 Preliminary evaluation

A preliminary evaluation is one of the priorities before testing for global fit, to test for anomalies that can skew any results (Bagozzi & Yi 1988). The most common anomalies tested are exceptionally large or small parameter estimates, negative error variances, large standard errors, or correlations closer to or greater than one (Bagozzi & Yi 1988; Byrne 2013). In order to verify the model's suitability, it is important to examine path estimates and their significance (Byrne 2013; Schumacker & Lomax 2004). The significance, strength and sign of path estimates are important (Byrne 2013; Shah & Goldstein 2006). Out of those, sign points towards the direction of the relationship suggests the (positive/negative) manifest variables' relationship to the latent variable. Given that the strength is verified by the significance of the parameter estimates, those statistically significant parameter estimates reveals the manifest variable's relationship to the latent variable. For factor loadings, standardised values greater than 0.6 are recommended (Bagozzi & Yi 1988). However, the values greater than 0.5 is worth retaining (Hair et al. 2014). As standard errors of the path estimates indicate the stability of the parameters, they should be smaller (Shah & Goldstein 2006). Therefore, standard errors below 0.4 are appropriate to retain (Bagozzi & Yi 1988). However, insignificant parameters should be eliminated (Byrne 2001). Model identification problems, model specification errors or incorrect input can create anomalies (Bagozzi & Yi 1988). Before evaluating the global fit measures, these possible grounds were examined. Therefore, a distinctive set of parameters that was consistent with the data was identified (Byrne 2013). The number of unknown parameters that is to be estimated should exceed (over-identify) or be equal to the number of data points (the number of unique variances and covariances) to satisfy the identification requirements (Byrne 2013; Hair et al. 2014).

4.3.1.4.2.5 Model fit assessment and global measures of fit indices used

The most fundamental event in SEM analysis is the confirmation of whether the measurement model is valid; therefore, is crucial to establish an acceptable level of goodness-of-fit (GOF) for the measurement model (Hair et al. 2014). How well the specific model reproduces the observed covariance matrix among the indicator items is signified by the goodness-of-fit, calculated by comparing the similarity between observed and estimated covariance matrices (Hair et al. 2014). Therefore, the 'model fit' is a comparison between an estimated population covariance matrix and the sample covariance matrix (Ullman & Bentler 2003).

Three types of model fit indices are used to verify he model fit, which are absolute, incremental and parsimonious indices (Hair et al. 2014; Schumacker & Lomax 2004). The absolute fit indices transpire as a direct measure demonstrating the extent to which observed data is reproduced by the specified model (Hair et al. 2014; Kenny & McCoach 2003). It demonstrates how well the estimated model regenerates data (Hu & Bentler 1999). By evaluating the extent to which the theory fits the sample data, the most basic assessment is provided by absolute fit indices (Hair et al. 2014). In contrast, the incremental fit indices assess the extent to which the estimated model fits in comparison to an alternative baseline model, which is also called a null model, that assumes all observed variables are not correlated (Hair et al. 2014). It represents a model fit improvement in comparison with a baseline model (Hair et al. 2014; Hu & Bentler 1998; Schumacker & Lomax 2004). The parsimonious indices consider its fit relative to its ability to provide information to identify the best fitting model among competing models (Hair et al. 2014). The measure is improved by a simpler model or a better fit (Hair et al. 2014). Selection of a simpler model with fewer free parameters is supported by the parsimonious indices (Blunch 2012; Hu & Bentler 1995). The number of estimated coefficients required to reach a certain degree of fit is revealed by parsimony (Schumacker & Lomax 2004). Parsimonious indices are not helpful for the evaluations of a single model, but they are extremely effective for the comparison of the fit of two models with different complexities (Hair et al. 2014).

In order to evaluate model fit, a number of absolute, incremental and parsimonious fit indices were considered (Hu & Bentler 1999). Table 4.5 describes the considered fit indices for model evaluation.

Table 4.5 The fit indices considered for model evaluation.

The index	Description
Absolute fit indices	
X²	The most fundamental absolute fit index (Hair et al. 2014). The only statistically-based SEM fit measure (Byrne 2013). A significant x^2 value indicates the disparity between observed and estimated matrices, where zero indicates a perfect fit with identical observed and estimated matrices. Accordingly, smaller x^2 values indicate a better fit (Hair et al. 2014; Hu & Bentler 1995). What non-significant x^2 value suggests is that the theorised model of the study is not significantly different to the observed model (Schumacker & Lomax 2004). However, the test is sensitive to the number of observed variables (Hair et al. 2014), the sample size (Anderson & Gerbing 1988; Bagozzi & Yi 1988; Hair et al. 2014) and multivariate non-normality of the data (Hu, Bentler & Kano 1992; Schumacker & Lomax 2004). Therefore, it is not used as a solitary GOF measure (Hair et al. 2014). In a case of a non-normal data, application of bootstrapping is advisable when conducting x^2 tests (Bollen & Stine 1992). The bootstrap modification of the standard x^2 is represented by the Bollen-Stine *p* value (Bollen & Stine 1992). It can provide improved results in multivariate conditions (Ory & Mokhtarian 2010). Accordingly, no variance between observed and estimated variance or covariance matrices is suggested by a p value above 0.05 (Byrne 2013; Jöreskog & Sörbom 1982).
Goodness-of-fit index (GFI)	GFI is one of the initial fit statistics, which is not that sensitive to sample size (Hair et al. 2014; Maiti & Mukherjee 1991). GFI values over 0.9 are considered good (Bentler & Bonett 1980; Hair et al. 2014). GFI is augmented with the sample size, where, in smaller samples, the value diminishes with the increment of the number of items per factor or the number of factors in the tested model (Anderson & Gerbing 1984). Therefore, in smaller samples ($n <= 250$), GFI index performs poorly (Hu & Bentler 1995). Due to the recent advancement in fit indices, the use of GFI has declined (Hair et al. 2014).
Root mean square error of approximate-on (RMSEA)	Widely used measure that tries to address the x^2 tests issues with the number of observed variables and the sample size by including both sample size and model complexity in the computation (Hair et al. 2014). RMSEA evaluates the lack of model fit compared to a saturated model (Ullman & Bentler 2003). A value over 0.1 suggests a poor fit, while a value between 0.08 to 0.1 implies an ordinary fit (Byrne 2013). A value less than 0.08 is acceptable (Hair et al. 2014). The RMSEA value is affected by choice of estimation method (Ullman & Bentler 2003). This index is not the best option for ML estimation with smaller samples as true-population models can be over rejected. Therefore, the criterion is not recommended for smaller samples ($n<250$) (Hu & Bentler 1998; Hu & Bentler 1999). Higher RMSEA values imply the worst fit, therefore it is categorised as a badness-of-fit index (Hair et al. 2014).
Standardised root mean square	SRMR also falls into the category of badness-of-fit measure (Hair et al. 2014). SRMR indicates the mean residual between the estimated and observed variance and covariance

residual (SRMR)	matrices (Hair et al. 2014; Ullman & Bentler 2003). This index can be applied to compare different models using the same data set (Bagozzi & Yi 1988). A value below 0.8 is considered acceptable (Hair et al. 2014; Hu & Bentler 1998). SRMR indices is not recommended for smaller sample sizes (n < 250), as criterion is less sensitive to distribution non-normality and the sample size (Hu & Bentler 1998).
Normed X^2 (X^2/df)	Normed x^2 is the ratio of x^2 to the degree of freedom of a model (x^2/df) (Hair et al. 2014). Normed x^2 can help recognise over-identified models and reveal the models that do not fit the observed data (Schumacker & Lomax 2004). The values between one and two suggest a good fit, whereas a value less than 1 indicates an over-fit and a higher value (>3-5) indicates an under-parameterised model (Bollen 1989). The index is widely used (Hair et al. 2014). Normed x^2 can also be used as a parsimonious fit index (Schumacker & Lomax, 2004).
Incremental fit indices	
Normed fit index (NFI)	NFI is one of the earliest incremental fit indices (Hair et al. 2014). To evaluate the estimated model, it contrasts the x^2 value of the tested model against the x^2 value of an independent model (Ullman & Bentler 2003). NFI value ranges between zero to one, where a greater value than 0.9 suggests a good fit (Hu et al. 1992). However, NFI is reported to underestimate fit in smaller samples (Hu & Bentler 1999). It is moderately sensitive to complex model mis-specification and less sensitive to simple model mis-specification (Hu & Bentler 1998). NFI is used less at present, in favour of other incremental fit indices (Hair et al. 2014).
Tucker-Lewis index (TLI)	TLI index is conceptually similar to NFI, but compares the normed x^2 values for the null and specified model, therefore takes model complexity into account (Hair et al. 2014). It is an adjusted NFI to the degrees of freedom, and also called a non-normed fit index (NNFI) (Ullman & Bentler 2003). TLI is not normed, therefore it can range from below zero to above one (Hair et al. 2014). While one represents a perfect fit, a value close to zero indicates no-fit, where a value of over 0.9 suggests a good fit (Bentler & Bonett 1980).
Comparative fit index (CFI)	CFI is an improved version of NFI (Bentler 1990; Bentler & Bonett 1980). The values range from one to zero, with values above 0.9 suggesting a good model fit (Bentler & Bonett 1980). It is reliable even with smaller samples (n<250) and less sensitive to the nature of distribution (Hu & Bentler 1998). CFI is relatively insensitive to model complexity (Hair et al. 2014). It is less sensitive to simple model mis-specification and moderately sensitive to complex model mis-specification (Hu & Bentler 1998). Due to its desirable properties, CFI is one of the most widely used indices (Hair et al. 2014).
Parsimonious fit indices	
Adjusted goodness-of-fit (AGFI)	AGFI tries to take a differing degree of model complexity into account (Hair et al. 2014). AGFI is the GFI adjusted to the degrees of freedom relative to the number of parameters (Byrne 2013). It indicates the hypothesised model's relative degree of variances and covariances (Bagozzi & Yi 1988). The values range from one and zero, with values above

	0.9 considered to be the cut-off for model selection (Hu & Bentler 1999). AGFI is insensitive to the nature of normality of the data but is sensitive to sample size (Hu & Bentler 1999). It over-rejects models when tested with smaller sample sizes (Hu & Bentler 1995). AGFI is rarely used in favour of indices which are less sensitive to sample size and model complexity (Hair et al. 2014).

Fit indices that can uncover a greater degree of model mis-specification, least influenced by the sample size, distribution and the estimation method are the best suited (Hu & Bentler 1998). Out of the considered fit indices, Goodness-of-fit index (GFI) and Adjusted goodness-of-fit (AGFI) can be overly influenced by the sample size (Fan, Thompson & Wang 1999; Maiti & Mukherjee 1991). Similarly, Normed fit index (NFI) underestimates fit in smaller samples (Iacobucci 2010). Since CFI is an upgraded version of NFI, application of CFI as an index of choice over NFI is suggested (Bentler 1990; Byrne 2013; Hu & Bentler 1999). Consequently, given the recently developed, much more relevant, fit indices, GFI, AGFI and NFI are rarely applied today (Hair et al. 2014). The GFI, AGFI and NFI were not considered as suitable fit indices in the model evaluation, specifically on the complex combined full model, because of their poor performance in small samples ($n < 250$) (Hair et al. 2014; Hu & Bentler 1998; Hu & Bentler 1999). Appropriately, the current literature (Flynn et al. 2010; Huo 2012; Ralston et al. 2015; Wong et al. 2011a; Yu 2015) on similar themes in operations and supply chain management arena has avoided applying the above fit indices.

The objective of a better model fit may cause inferior practices in model specification. This is not a worthy compromise because such a reduction of the number of manifest variables per latent variable may jeopardise the investigation of theory (Hair et al. 2014; Kenny & McCoach 2003; Marsh et al. 1998). Hair et al. (2014, p. 583) suggest using “3 to 4 fit indices provides adequate evidence of a model fit” in general. Applying several fit indices of different index types and adjusting index cut-off values based on model characteristics is suggested to establish an acceptable fit (Hair et al. 2014). Hair et al. (2014) suggest x^2, CFI or TLI, SRMR and RMSEA. They consist of an absolute fit index, an incremental fit index, a goodness of fit index and a badness of fit index as suitable combination of fit indices to test a model consisting of over 30 measurement items with a data sample of less than 250 cases.

The x^2 test is the only statistical test that evaluates the differences between the matrices in structural equation modeling that indicates the model’s accuracy (Hair et al. 2014;

Schumacker & Lomax 2004). However, the x^2 is sensitive to sample size and number of indicator variables (Bentler 1990; Gerbing & Anderson 1985). Since numerous factors influence the x^2 significance test, it is possible to have reservations about almost any result (Hair et al. 2014, p. 582). In addition, the applicability of the x^2 test to evaluating model fit has been criticised, since when the data deviates from multivariate normality, it leads to model rejections (Hu et al. 1992; Schumacker & Lomax 2004). The sample was identified as multivariate non-normal. Therefore, the Bollen-Stine bootstrap x^2 test was considered as reinforcement. Bootstrap methods (Efron 1992) can substitute as a second option when fitting covariance structures in conditions of non-normal data (Bollen & Stine 1992; Tomarken & Waller 2005). Simulation studies suggest that the bootstrap performs well in varied distribution shape and sample size (Enders 2002; Nevitt & Hancock 2001). Without replacement from the original data, by means of resampling, bootstrap methods can empirically generate sampling distributions (Tomarken & Waller 2005). Therefore, researchers can estimate accurate significance levels by using bootstrap samples (Bollen & Stine 1990). However, the bootstrap also generates inaccurate results for covariance structures in a very small sample size ($n < 100$), (Nevitt & Hancock 2001; Tomarken & Waller 2005).

Hair et al. (2014, p. 584) stipulate that an insignificant p-value should not be expected for a model with over 30 measurement items if the observed variables are fewer than 250. The Bollen-Stine p-value was considered in that case (Bollen & Stine 1992; Enders 2002). However, an insignificant p-value should be expected in a case of fewer than 250 observed variables if the number of items is less than 12 (Hair et al. 2014, p. 584). Both scenarios were applicable in this study, given that the cognitive measurement models of each construct (<12 items) were tested in isolation before testing the complete full measurement model (>30 items) with all six constructs.

The outcome from the full CFA model was then evaluated for reliability and validity (Byrne 2013; Hair et al. 2014; Schumacker & Lomax 2004).

4.3.1.4.2.6 Reliability assessment

Reliability is an indicator of convergent validity (Hair et al. 2014), confirming the consistency of the measures (Sekaran 2006). For multiple-item measures such as those used in this study, internal reliability is the most satisfactory measure of consistency (Bryman 2015; Clark & Watson 1995). Internal reliability suggests homogeneity of the measurement items (DeVellis 2003; Sekaran 2006). If the items on a scale are highly intercorrelated, the scale is internally consistent—the items are measuring the same construct (DeVellis 2003). There are several possible reliability estimates (Bacon, Sauer & Young 1995). Coefficient alpha is the most commonly applied reliability estimate (Hair et al. 2014; Slavec & Drnovsek 2012). The Cronbach (1951)'s alpha internal reliability measure evaluates reliability by computing all possible split-half reliability coefficients of the measurement items of a theory (Dubester & Braun 1995). It represents the mean of all split-half coefficients resulting from the different splitting of a test (Cronbach 1951; Slavec & Drnovsek 2012). Cronbach's alpha reliability estimates above 0.7 represent good reliability (Hair et al. 2014; Nunnally 1978). However, some suggest an alpha value above 0.8 as a reliable measure (Clark & Watson 1995).

The construct reliability (CR) values were also computed for each construct. The below formula was used to calculate CR. A CR value above 0.7 suggests good reliability (Hair et al. 2014).

$$CR = \frac{\left(\sum_{i=1}^{n} L_i\right)^2}{\left(\sum_{i=1}^{n} L_i\right)^2 + \left(\sum_{i=1}^{n} e_i\right)}$$

L_i = Squad sum of factor loading.

e_i = Sum of error variance terms.

Internal consistency can be assessed with inter-construct correlations. The correlations between constructs were also tested to see whether there were any multicollinearity issues between constructs. The correlations below 0.8 indicate no multicollinearity issues (Hair et al. 2014).

The magnitudes of the factor loading are also a key consideration. Therefore the item reliabilities were further confirmed by assessing factor loadings. The standardised factor loadings should be at a minimum of 0.5, but the ideal value is above 0.7 (Hair et al. 2014). The measurement items with factor loadings above 0.71 possess a greater shared variance with the construct than the error variance (Hair et al. 2014; Jöreskog & Sörbom 1982). The reliability values should be statistically significant (Anderson & Gerbing 1988; Hair et al. 2014).

4.3.1.4.2.7 Construct validity assessment

Validity confirms the extent to which the research is accurate (Hair et al. 2014). Validity suggests the accuracy of the measurement indicators in capturing the theory (Bentler &

Bonett 1980; Bryman 2015; Hair et al. 2014; Sekaran 2006). A number of validity forms, including content and construct validity, were assessed at different stages in this study.

Content validity is the adequacy of the measurement instrument and includes items regarding the sufficient relevance and representativeness of the study construct (Haynes et al. 1995; Slavec & Drnovsek 2012). Examining face validity can verify the content validity of measures of unobservable constructs (Hardesty & Bearden 2004). Face validity verifies the measurement items' ability to capture the concept (Hardesty & Bearden 2004; Sekaran 2006). The expert judges' and knowledge experts' reviews were used to improve the face validity during the measurement scale development process (DeVellis 2016; Hardesty & Bearden 2004).

Construct validity confirms whether the measured items, in reality, manifest the theoretical latent construct the items are designed to measure (Hair et al. 2014). In an attempt to confirm construct validity, both convergent and discriminant validity of the constructs were tested. Convergent validity measures whether the manifest variables of the construct share a high proportion of variance or correlation (Hair et al. 2014). Factor loadings should be statistically significant and also standardised loadings estimates should be greater than 0.5 or, ideally, higher than 0.7 (Hair et al. 2014). The average variance extracted (AVE) value for each construct was computed to examine convergent validity. The AVE is a summary measure for convergence between the items representing a latent construct, represented by the average % of variation among items of a construct (Hair et al. 2014). AVE which is calculated by dividing the total of squared factor loadings (Squared Multiple Correlations) by the number of items, stand for the extent of item variation explained by the construct (Fornell & Larcker 1981; Hair et al. 2014). An AVE value beyond 0.5 confirms convergent validity (Hair et al. 2014).

In opposition to convergent validity, discriminant validity evaluates the extent to which the constructs are unique and distinct from each other to capture phenomena that the other constructs do not (Hair et al. 2010). It looks for the absence of correlation between measures of unrelated constructs (DeVellis 2003). The presence of cross-loadings creates a discriminant validity problem, therefore the items loaded on multiple factors were eliminated (Hair et al. 2014). The discriminant validity was verified by testing the correlations between the latent variables of the measurement scale by applying two common CFA methods (Hair et al. 2014). Firstly, a nested model comparison was carried out (Anderson & Gerbing 1988; Bagozzi & Yi 1988; Hair et al. 2014). A series of CFA models were compared by constraining the correlations between each pair (one pair at a time) of constructs equal to 1. Discriminant validity is supported, if the x² difference is significant between the models (Bagozzi & Yi 1988; Hair et al. 2014).

In reality, however, the nested model comparison does not provide strong evidence of discriminant validity, as even correlations as high as 0.9 can sometimes produce a significant difference in fit (Hair et al. 2014). Therefore, to reinforce the argument for the discriminant validity of the constructs, they were tested by comparing the AVE value of each construct against squared correlations of remaining constructs. The AVE value should be above correlation estimates (Fornell & Larcker 1981; Hair et al. 2014). If the AVE of a construct exceeds the squared correlations of remaining constructs, the latent construct explains more of the variances in its items than the variance it shares with other constructs (Fornell & Larcker 1981; Hair et al. 2014). Passing this more rigorous test better evidence of discriminant validity (Hair et al. 2014, p. 620).

4.3.1.4.2.8 Common method bias

The threat of common method bias for such single source SEM-based supply chain research designs is high in general (Hazen, Overstreet & Boone 2015). To enhance the validity of the measures, the threat posed by common method bias must be addressed (Hazen et al. 2015; Malhotra et al. 2006). It exaggerates the relationships between variables attributable to the variance caused by the data collection methods (Chang, Van Witteloostuijn & Eden 2010; Conway & Lance 2010). Method biases can falsify the validity of the survey results by producing measurement errors (Podsakoff et al. 2003). Common method variance (CMV) tests were applied to address the common method bias issues that could result from collecting perception-related data using a self-reporting questionnaire from a single respondent from a company. Common method bias may affect the results of self-administered questionnaires with perceptual measures, even if the same respondent responds on different occasions (Chang et al. 2010; Lindell & Whitney 2001). The nature of the questions can also increase social desirability bias as the questions are based on the best technology practices, performance effects and sometimes even social and environmental outcomes (Chang et al. 2010; Ganster, Hennessey & Luthans 1983). Multiple counter-actions at various stages are advised to address method biases (Chang et al. 2010; Podsakoff et al. 2003). Especially in circumstances where SEM is applied to the data collected via a single method, common method bias must be addressed and the evidence of lack of bias or control for bias must be reported (Hazen et al. 2015).

The wording of the questionnaire was carefully managed to reduce social desirability bias. Including both positively and negatively worded questions to discourage answering in patterns is a recommended approach (Baumgartner & Steenkamp 2001; MacKenzie & Podsakoff 2012). Despite some dissertations (DeVellis 2016; Podsakoff et al. 2003) negatively reflecting on the inclusion of negatively worded items due to their lower correlations with other items, researchers (Baumgartner & Steenkamp 2001; Churchill 1979; MacKenzie & Podsakoff 2012; Weijters & Baumgartner 2012) have generally endorsed carefully designed negatively worded items to counter method biases. The questionnaire design stage was carefully managed to spread negatively worded items throughout the questionnaire (Weijters & Baumgartner 2012). As the scale format affects the biases, a seven point Likert scale with a mid-point was used (Weijters, Cabooter & Schillewaert 2010).

Despite having the counter measures in place at the design stage, statistical methods to test common method biases were enforced. Podsakoff et al. (2003) suggest performing the Harman (1967) single-factor test applying both EFA and CFA. Common method bias is assumed to exist, when using the EFA-based method, a single factor accounts for the majority of variance in the variables or notably, if the results indicate a single factor solution (Podsakoff et al. 2003). All the manifest variables are loaded into a single latent variable, when applying the CFA-based method, and if the single factor model fits better than the original theoretical model, common method bias is assumed to exist (Malhotra et al. 2006). However, Harman's single-factor test has been criticised for being unreliable and is now considered outdated (Malhotra et al. 2006). Therefore, the Lindell and Whitney (2001) marker variable technique was also employed to confirm the absence of common method bias. The marker variable was theoretically unrelated to the other dependent variables (Lindell & Whitney 2001; Malhotra et al. 2006). During the questionnaire design stage, the Australian tourism industry questions (Q7_1 to Q7_4) were placed as the marker variable. When the marker variable construct is introduced to the full CFA measurement model, if there is a meaningful correlation between any study contracts and the marker variable, the existence of common method bias is assumed (Lindell & Whitney 2001; Malhotra et al. 2006).

4.3.1.4.2.9 Measurement invariance

It is a logical prerequisite to verify measurement invariance across groups when conducting substantive cross-group comparisons in organisational research (Vandenberg & Lance 2000). When the survey was administered to two or more qualitatively distinct groups, the data should be tested to confirm whether the outcome from the populations is comparable on the same measurement scale (Widaman et al. 1997). Therefore, measurement invariance was tested to confirm that the measurement model is consistent across different distinct groups of respondents (Hair et al. 2014). It was important to verify measurement invariance given that the sample represents organisations of various sizes, retail forms and supply chain spans. Thus it was tested as suggested by Myers et al. (2000) .

First, by testing the measurement model for separate individual groups, the configural invariance was verified. The configural invariance is the similarity of an instrument's syndrome structure across groups (Vandenberg & Lance 2000). The existing model served as a baseline model to compare when testing for metric invariance (Byrne 2013). Metric invariance is achieved when all factor loadings are equal across groups (Vandenberg & Lance 2000). Subsequently, the measurement models belonging to all groups were simultaneously analysed. Thereafter, the two models were compared as constrained and unconstrained models, to determine the metric invariance (Byrne 2013). During which, variances, covariances, factor loadings and error variances were set to be equal across groups in the constrained model, while all the parameters were freely estimated in the unconstrained model. It implies that the constrained model is nested within the unconstrained model (Byrne 2013). A non-significant x^2 value indicates a measurement invariance (Hair et al. 2014; Myers et al. 2000). Even though the nested models can be tested via x^2 difference test, it has been questioned for its suitability for invariance decisions (Byrne 2013; Hair et al. 2014). given that CFI difference does not depend on the sample size or model complexity, or neither does correlate with overall fit measures, better approach is to assess the differences in CFI values between constrained and unconstrained models (Cheung & Rensvold 2002; Hair et al. 2014). If the difference between the CFIs of the two models is greater than 0.01, then measurement invariance in likely indefensible (Cheung & Rensvold 2002). Therefore, to be rigorous, both x^2 and CFI differences were evaluated.

4.3.1.4.2.10 Structural analysis

Once the measurement model is verified, the Anderson and Gerbing (1988) two-step approach for SEM then suggests testing the structural model (Huo, 2012; Yu et al., 2013). The structural model being tested is the conceptual framework hypothesised earlier in linking the observed variables to latent variables and also linking latent variables to each other (Byrne 2013). The objective of this testing is to confirm the relationships among the latent variables and to reject or fail to reject the model (Byrne 2013). By testing how well the observed data fits the restricted hypothesised model, it can define the explained and the unexplained variance in the theoretical model (Byrne 2013). Given that the structural model is nested within the measurement model, it is unlikely that the structural model would fit better than the full measurement model (Byrne 2013; Hair et al. 2014). Therefore, the standardised ß (beta) coefficients of the path estimates along with the p values were examined. To identify the extent to which the variance in each construct is explained by the model, R^2 values (variance explained estimate of endogenous constructs) were also examined (Byrne 2013; Hair et al. 2014).

4.3.1.4.2.11 Hypotheses testing

The results of the structural path model were used to test the nine hypotheses proposed in Chapter 3. A t value above 1.96 indicates significant paths at $p < 0.05$ (Byrne 2013). However, $p < 0.001$ indicates that the hypothesis is strongly supported (Su & Yang 2010). R^2 values were also assessed to identify to what degree the manifest variables explain the variation in latent variables.

4.3.1.4.2.12 Testing the effect of control variables

Once the structural theory was confirmed, the structural model using structural equation modelling was then examined for the possible confounding effects of the control variables, as they can affect the relationships. The firm size and retail model were the control variables used in this research. Firm size, graded by the number of employees working for the organisation, was used as a controlled variable as larger organisations have more advanced resources to manage supply chain activities and may have better technological deployment in their supply chain operations to achieve a higher level of IoT deployment in comparison to smaller organisations (Rai et al. 2006; Yu 2015; Zhao et al. 2011). The classification of the Australian Bureau of Statistics (ABS Retail industry analysis 2014; ABS_ANZSIC 2013) for organisation size was applied to this study. The organisation's retail form was controlled because organisations conducting business differently may have different influences on process and technology capabilities and different intensities of IoT-enabled SCI and performance. Therefore the retail business form of respondents in terms of bricks-and-mortar, multi-channel or e-tail (ABS Retail industry analysis 2014; ABS_ANZSIC 2013) was identified. Whether the control variables have a significant effect ($p < 0.05$) was verified (Byrne 2013). The test can rule out any confounding effect of demographic variables to confirm the internal validity of the research (Rai et al. 2006).

4.3.1.4.2.13 Post-hoc analysis and model re-specification

Post-hoc analysis is follow-up tests after the theory test to explore the relationships where the original theory does not have a path (Hair et al. 2014). It involves assessment and re-specification of recursive structural models in SEM (Hair et al. 2014; Shah & Goldstein 2006). In order to look for evidence of improvement, exploring at least one nontrivial competing model with a likelihood of representing the current literature on which the structural model is built upon is suggested (Iacobucci 2010). The models are considered for re-specification if there are any monitored mis-specifications identified through the standardised residual values as well as modification indices (Byrne 2013). The unexplained variance in a hypothesised model is accounted by standardised residuals (Bagozzi & Yi 1988). Residual values above 2.58 ($p < 0.005$) are too large to consider (Jöreskog & Sörbom 1982). Modification indices greater than 4 (3.84) ($p<0.05$) can significantly improve the model by freeing the corresponding path (Hair et al. 2014). However, providing the tested path is not supported by the original theory, relationships identified post hoc are not as reliable as the original theoretical relationships (Hair et al. 2014). Therefore, any model re-specification must have a strong empirical and theoretical support (Bagozzi & Yi 1988; Hair et al. 2014). Despite model re-specification being suggested by indicative measures in SEM, post hoc analysis cannot suggest an improvement to the model without cross-validating the improvement using new data from the same sample population and without a solid theoretical justification (Hair et al. 2014).

4.3.2 Qualitative phase

To support, interpret and validate the survey findings and to add depth and insight into the study, a qualitative inquiry was conducted on organisational case studies from a cross section of the retail industry. This phase was designed not only to gain in-depth insight into the survey findings, but also to uncover the actual IoT technologies and practices used by Australian retail supply chains to improve their integration processes in order to answer the research question two. The interviews were designed to triangulate the data from the survey, that is, to offset the inflexibility and the possible lack of detail in survey data, as well as draw important process information that can enhance the value of the collected survey data (Flint et al. 2012).

Case studies are regularly utilised in supply chain management research (Childerhouse & Towill 2011; Wamba 2012). A case study is a thorough analysis of a distinctive entity, emphasising occurrences of the circumstance (Denzin & Lincoln 1994; Thomas 2010; Yin 2009). Case studies focus on entities (organisations, individuals, sectors, industries) or events at a given point in time. It is this focus that defines the case study rather than the tools used to collect and analyse data (Willig 2008). A variety of methods can be used to collect case study data including interviews, observations and document analysis (Denzin & Lincoln 1994; Flynn et al. 1990). The limitation of this method is that the results are not generalisable; however, the purpose of this method is to provide in-depth indicative data (Denzin & Lincoln 1994; Flynn et al. 1990). Moreover, the survey data already provided a broader macro overview.

Data was collected using individual semi-structured interviewing. The most frequently used data collection method in qualitative research is interviewing (Bluhm et al. 2011; Kallio et al. 2016). Since supply chain practices were examined from the focal retail firm perspective, one-on-one interviews with representatives of respective firms were conducted in person or via Skype (with interstate informants), at the participants' convenience. Besides the interview content, those one-on-one interviews provided further rich data by allowing the interviewer to grasp background information and engage in informal communication (Richards 2014; Yin 2009). Moreover, the technique also enabled the collection of participants' perceptions of IoT enabled supply chain practices and their effect on the integration process.

4.3.2.1 Population and sampling

Recruitment of participants started at the survey stage. The retailers gave an expression of interest (EOI) by providing an email and a contact person name. The selection of the retail organisations was based on the fact that they have deployed IoT to capture data in logistics flow or their plans to do so. The selected retail organisations were approached via e-mail and invited to be a voluntary participant for this phase of the study. Twelve (12) retail industry participants were interviewed via purposive sampling, where the most suitable respondents from an identified organisation were approached to participate in the interview (Bryman 2015; Creswell & Poth 2017; Yin 2009). The participant selection aimed to include participants from retail firms across various sectors. The respondents represented medium and large companies and also both bricks-and-mortar, e-tail and multi-model organisations. Overall, the 12 participants held management positions and represented various retail subdivisions or sectors used in the survey study (ABS Retail industry analysis

2014; ABS_ANZSIC 2013). The interviewees profiles and their retail industry subdivisions are displayed in Table 4.6. Given that the purpose of interview data was to use as a secondary method to interpret/validate/explain the survey findings, interview data believed adequate for that purpose representing early and late IoT adopters, various retails forms and sizes, and all retail sub-divisions of the ANZSIC classification were collected (Flint et al. 2012).

Target respondents were recruited from supply chain management and IT management departments of retail firms who possess technology-enabled supply chain management knowledge. As most of the retail respondents indicated the important role of third party logistics service providers in their respective supply chains fulfilling inbound and outbound delivery operations, and the extent IoT has transformed those logistics functions, a manager from a third-party logistics (3PL) service provider who services the retail industry was also interviewed to collect supplementary evidence on what IoT technology they have deployed and how that benefits their customers.

Table 4.6 The interviewees profile and retail subdivisions

Retail category	ANZSIC Subdivision	No. of participated firms
Restaurant, café, takeaway	Subdivision 41	1
Supermarkets, grocery	Subdivision 42	2
Household goods (e.g. hardware, furniture)	Subdivision 42	1
Clothing, footwear and personal accessories	Subdivision 42	1
Electrical, electronic, computer	Subdivision 42	2
Pharmaceutical, cosmetic, toiletry	Subdivision 42	1
Motor vehicles & parts	Subdivision 39	1
Fuel and convenience stores	Subdivision 40	1
Department stores	Subdivision 42	1
Other	Subdivision 42	1

Source: ABS (Australian and New Zealand standard industrial classification (ANZSIC) 2006)

4.3.2.2 Interview protocol and pilot testing

This study utilised semi-structured interviewing to help gain rich insights into the core themes. A list of pre-determined questions (interview schedule) guided the semi-structured interview process, with the added flexibility to accommodate questions conforming to the interview context (Brinkmann 2014; Kallio et al. 2016). Semi-structured interviews enable flexibility for the respondent's spontaneous descriptions and narratives, while also offering structure to capture respondents insights in a systematic manner (Denzin & Lincoln 1994; Yin 2009). The use of open-ended questions enabled the participant to engage in an open manner within the set framework, to bring up new facts and ideas throughout the interview process. It allowed the researcher to pose "how" "why" questions, but also to probe and explore knowledge areas that had not been anticipated. The questions were designed based on hypothesised relationships in the conceptual framework (Figure 3.1). The open-ended questions were focused on verifying the relationship between IoT capability, SCI and performance and on the specific enabling IoT technologies and practices.

The interview schedule (see Appendix H) had 19 questions under two sections which focused on general information about the respondents and IoT enabled supply chain practices respectively. Section 1 was mainly on information about the representative firm and the respondent's background in the focal retail firm. Section 2 asked about when the respondent organisations first adopted IoT and their motives and drivers to do so. Following this, participants were asked to reflect on the IoT technologies deployed in-house, supplier-related and customer-related operations and their respective performance outcomes. Simultaneously, their future IoT deployment plans in their in-house, supplier-related and customer-related operations and expected outcomes were also examined. Then participants were directed to reflect on how IoT deployment in internal processes affected external relationships, and in turn, how IoT deployment in all three supply chain dimensions influence the performance of the supply chain and in turn the focal firm. IoT enabled supply chain performance outcomes were discussed in terms of traditional cost, quality, delivery, and flexibility dimensions and firm performance outcomes were probed under prevailing triple bottom lines in economic, environmental and social sustainability. The respondents were then asked about their exploitation of captured IoT data followed by what they think are the obstacles to IoT deployment and obtaining best outcomes from it. Finally, an open-ended question was asked on whether they had anything important to say that was missed during the interview.

The wordings of the questions were cautiously examined to reduce social desirability bias that may lead respondents to answer the questions favourably (Nederhof 1985). The draft interview schedule was first reviewed by the supervisors. Then a discussion was held to evaluate the appropriateness of the questionnaire, where the length, the breadth and the word expressions were examined. The revised interview schedule was further tested for appropriateness through pilot interviews ahead of the target respondents. Pilot interviews conducted face-to-face with three managers in the retail industry verified the relevance of the questions, and the reliability and validity. In order to minimise bias during the pilot interviews, commenting on responses and providing clarification unless otherwise asked was avoided. The respondents were not interrupted unless the answers were exceedingly prolonged or far deviating from the focus. The same consistent approach was adopted for the final interviews. The pilot interviews lasted for between 45 minutes to 1 hour and audio recorded. Subsequently, feedback on the clarity of questions and suggested improvements were provided by the subjects of the pilot study. Minor improvements to the interview schedule were made through the feedback. The feedback was used to revise and improve the final questionnaire. The interview schedule finally employed in this study is attached as Appendix H.

4.3.2.3 Arranging and conducting interviews

Recruitment of participants was conducted at the survey stage where the interested organisations completing the anonymous survey were asked to provide an email and a contact person for further investigation if interested. The selection of the retail organisations was based on the fact that they have deployed IoT to capture data in logistics flow or their interest and plans to do so. The selected retail organisations were approached via the provided e-mail to invite to be a voluntary participant for this phase of the study. In most instances, the initial contacts themselves volunteered to be interviewed or another volunteer was nominated (after passing gatekeepers). Negotiation with gatekeepers such as CEOs, Heads of HR and Directors was carried out in some cases, when an intervention for organisational permission process was required, but was mainly left to the discretion of the voluntary participants who are top level employees of the firm (Bryman 2015; Denzin & Lincoln 1994; Yin 2009). Once consent was granted, the formal information sheet for individual interview participant organisations (Appendix C) was sent. The information sheet included the research objectives, purpose of the interview, how long it would take, potential research contributions and anonymity guarantees. Management scholars have reasoned that, to get a higher chance of acceptance from potential participants, the time and resource requirement should be kept to the minimum feasible (Easterby-Smith, Thorpe & Jackson 2012). Hence, the interviews were limited to approximately an hour and only a single voluntary informant was invited from each organisation.

The time and place for the interviews were scheduled at the informants' convenience. All interviewees were provided with a hard copy of the information sheet for individuals

(Appendix C). All informants confirmed consent by signing the consent form (Appendix G) before conducting the interviews. The nature of research, potential benefits and related risks were outlined to the informants in an explanatory statement, who were also advised to gain consent from managers. They were advised of the choice (informed consent) of participation and withdrawal (Corbin & Morse 2003). Privacy and confidentiality of respondents were assured.

With permission, the interviews were recorded using a digital audio application on a smart phone and uploaded to a secure drive. The recordings enabled the researcher to corroborate the reliability of the interview data. However, if the informants expressed any reluctance about being recorded, a contingency plan was to make extensive notes of the interviews. To make the interviewees comfortable, to develop rapport and initiate the discussion, the first question centred on their organisational role. Leading questions were avoided to allow free flow of discussion (Denzin & Lincoln 1994; Richards 2014). Field notes were taken on the emerging themes. Interview process lasted from mid to end 2017.

4.3.1.4 Qualitative data analysis

Following the transcription of the 13 interviews, the software application Nvivo 11 was used to help the thematic analysis process. The field notes, websites, and in some cases, follow-up email and phone conversations supplemented the interview data.

A data reduction process was conducted, using an inductive approach to transform data into orderly and simplified themes to develop a meaningful outcome. Interviews were analysed using a typical open-coding process used in qualitative research (Creswell & Poth 2017; Strauss 1987). This process involved reducing and categorising the text into meaningful segments and labelling them with an appropriate title to best define the material (Creswell & Poth 2017; Yin 2009).

The code formation is contingent on the understanding and interpretation of the data (Richards 2014). Coding assists in understanding patterns through data abstraction. Three types of coding are found in typical qualitative analysis: descriptive, topic, and analytic coding (Richards 2014). Information on characteristics or attributes are denoted in descriptive codes and used to accrue demographic information as they were important to investigate patterns. Here "in Nvivo" coding (where the exact words of the respondents are used to label the code) was used frequently. Topic coding is classifying as per the key theme. Analytic coding is used to reinforce an emerging theory or to confirm theory and denote the reflections on the subject (Richards 2014). The analyses involved all three key coding types. A new code was created in any case where the content slightly deviated from the existing code.

Subsequent to the primary coding process, transcripts of each were examined to identify new themes, revise existing codes and establish sub-categories (Richards 2014). The codes were reviewed and, in some cases, consolidated to avoid repetition. The identification of key themes involved consolidating interrelated codes into broader groupings. Patterns and relationships were identified across the data (axial coding). The interview transcripts were combined with field notes at this stage and, when it was feasible, coded data were verified by web information (e.g. firm size).

The findings from the interviews helped gain an improved detailed understanding of the relationship between the study variables and extent of IoT deployment in the Australian retail industry to improve SCI for greater performance and other vital information on IoT deployment. The findings of the qualitative phase of the study are detailed in Chapter 6. The discussion of findings in Chapter 7 integrates the analysed outcomes of the survey with the insights gained from the case studies (Flint et al. 2012).

4.3.1.5 Trustworthiness

Trustworthiness covers characteristics such as credibility, transferability, dependability and conformability. Therefore, it is fundamental to be thorough with the methods and the results (Bryman 2015). Credibility of the study was confirmed at a later point through triangulation of quantitative and qualitative findings. Dependability was ensured by keeping complete records of data collection and analysis. Conformability was assured through good faith by dismissing personal values and theories. A high-quality digital recorder on a modern smartphone was used for audio-recording and transcribing the interviews, to ensure the data quality.

Semi-structured interviews could be subjected to data quality issues such as biases by the respondents (Saunders 2011). Care was taken to avoid bias at the design stage . Leading questions were avoided while conducting interviews. The innovative technology related interview responses can result in social desirability bias, as respondents may like to report that they are progressive. Therefore, data triangulation was utilised to reduce the effect of these biases and to improve the data accuracy (Denzin & Lincoln 2008). Triangulation is explained as the use of multiple information sources to balance out subjective influences to understand a phenomenon (Creswell & Poth 2017; Flick 2004).

The reliability of coding is vital as the coding process can be extremely subjective and dependent on the researcher's comprehension and interpretation. Therefore, inter-rater reliability was tested (Richards 2014). Inter-rater reliability tests are a way of comparing the uniformity of the codes created by two different individuals on the same transcript (Richards 2014). A second coder with no direct role in this study was used to verify the codes. A researcher with extensive qualitative coding experience coded transcripts for 4 interviews, and compared codes for discrepancies, to confirm a general agreement in coding consistency.

4.4 Chapter summary

The methodology applied in this study is explained in this chapter. The study philosophies, ontologies, epistemologies and methodologies were rationalised. The employed mixed methods approach was justified and the two phases adopted in this study were explained in detail. The steps followed to collect quantitative data via a survey of Australian retail organisations, in terms of scale development, questionnaire preparation and instrument validation techniques were discussed. The on-line questionnaire was sent to a random sample of retail organisations, and 231 complete responses were received. After initial screening, the data set of 227 cases were tested using the two-step approach of structural equation modeling, where the measurement model was tested before the structural model. The chapter detailed the SEM methodology, the model fit, reliability and validity tests and hypothesis testing. A quantitative survey study was followed by a series of semi-structured interviews in a qualitative case study phase. 12 retail industry managers and a manager from a 3PL service provider was interviewed. The qualitative data was first transcribed and then thematically analysed with the help of Nvivo 11 qualitative analysis program, where data reduction process transformed data into orderly and simplified themes. Data was analysed simultaneously, hence the next two chapters discuss the findings of the two phases together in an overall findings and discussion.

Chapter 5
Quantitative research findings

5.1 Introduction

The finding of the quantitative survey data is discussed in this chapter by explaining the stage by stage analysis procedure. It focuses on the measurement and structural models in SEM to validate the hypotheses developed in Chapter 3.

The preliminary analysis in section 5.2 discusses the details of the screening of the survey data for inadequate, unengaged, mechanical or unanswered responses, followed by missing value analysis. The assessment of univariate and multivariate distribution normality and outliers for each measurement item is followed. Then, in an attempt to justify the suitability of the study sample, the demographic evidence is scrutinised in section 5.3, under the characteristics of the organisation, their deployment of IoT in supply chain operations and the respondent's suitability for the study. The descriptive statistics for the measurement items are examined in section 5.4. Subsequently, the procedure for testing the measurement model is discussed in section 5.5. The measurement models for each construct were validated disjointedly by applying exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), prior to testing the full measurement model. The model fit of measurement models was assessed by applying CFA and using goodness-of-fit indices to guide towards model-fit. The reliability and validity of the final measurement model were confirmed in section 5.6 prior to structural analysis of the theoretical model in section 5.7. The structural model was also validated by the goodness-of-fit indices ahead of verifying the study hypotheses. To further validate the theoretical model, the effect of control variables on the structural model was tested to exclude any confounding effects and post hoc analysis was conducted to conclude that no model re-specification was possible.

The chapter concludes with a summary of the key survey findings.

5.2 Preliminary analyses

This section explains how the suitability of the survey response data was established and discusses the steps followed to transform the raw data to a suitable format for quantitative analysis. The survey generated 231 responses. The resulting data set was preliminarily tested for its appropriateness for multivariate statistical analysis (Hair et al. 2014).

5.2.1 Data screening

The sample data were screened to identify cases that might have been completed by unfitting respondents, answered in an unengaged or a mechanical manner (answered invariably to all questions or in a pattern) or not answered at all.

Question 13 on the category of retail industry and question 12 on retail form helped to filter out non-retail industry respondents. There was one questionnaire answered by an unsuitable respondent. The questionnaire was sent only to retail industry participants, which is the unit of analysis of this study. Despite thorough screening at the recruitment process, one respondent identified himself as a participant from the transport industry. Hence the questionnaire was discarded. Only the responses from the retail industry were progressed ahead.

There were no completely unanswered questionnaires. A thorough visual inspection confirmed that no questionnaires were either answered invariably or in a pattern (mechanically). Six responses were exhibiting a standard deviation less than 0.5 on all measurement items of latent variables. After a closer examination for invariability, three responses were discarded as unengaged responses.

At this stage, a total of 4 responses were disregarded reducing the sample to 227 cases, making the response rate 41%. The sample was then examined for missing values.

5.2.2 Missing value analysis and treatment

The data set was first examined for missing values. The cases with exceptionally high (over 50%) missing values were to be discarded as such cases are meaningless (Hair et al. 2014). There were, however, no such cases. There were only 21 missing values in total (0.14%) in manifest variables. There were only 2 cases with more than 5% missing data. Besides, no measurement item had over 1% missing data, which was ignorable (Hair et al. 2014). Therefore, all 227 cases were suitable to proceed. This outcome is mainly attributable to the validation options provided by Qualtrics such as "Request response" and also highlighting unanswered questions with customised javascript by the researcher.

When the missing data is less than 10%, any imputation method can be applied, unless missing data is non-random (Hair et al. 2010). Hence, further analysis was conducted to establish whether the missing value patterns are at random. As the first gauge, Little's 'missing completely at random' (MCAR) test (Little 1988) indicated a significant (p-value below 0.05) outcome, implying that the missing values were not MCAR. However, it is unrealistic to obtain a sample with MCAR characteristics in practice (Muthén et al. 1987; Raghunathan 2004). Therefore, the sample was further analysed to verify whether the missing value patterns were missing at random (MAR).

The separate variance *t*-test indicated that only one item (item 6.5) had missing variables (only 2 missing) that were predicted by the other variables except for the dependent variable. Accordingly, the sample demonstrated a MAR pattern, as nearly all (almost all but 1 item or 2 values) of the missing values were randomly distributed (Baraldi & Enders 2010; Tabachnick & Fidel 2013). An estimation method built on the maximum likelihood (ML) approach is suitable in MAR situations, therefore expectation maximisation (EM) method is appropriate (Allison 2003; Baraldi & Enders 2010). The EM method is more suited for data sets in MAR or MCAR conditions than other imputation methods (Byrne 2013; Hair et al. 2014; Tabachnick & Fidel 2013). The EM method has exhibited comparable estimations despite the share of missing values, where, for example, similar estimations were generated even with 32% of missing values, in comparison to 2% of missing values (Olinsky, Chen & Harlow 2003). Furthermore, the EM method can produce unbiased outcomes even with a sample as small as 100 (Olinsky et al. 2003). Even though any imputation method is applicable for fewer than 10% of missing data (Hair et al. 2014), in consideration of the sample size and the pattern of missing data, the EM method was chosen.

The missing values were substituted via EM method in SPSS 23. Thereafter, the sample was ready to be assessed for univariate/multivariate normality and outliers.

5.2.3 Distribution normality and outliers

At first, the univariate normality for each item was verified by using histograms to observe the shape of the distribution of data with skewness and kurtosis estimates alongside. A skewness and kurtosis of less than 3 and 10 respectively are tolerable (Kline 2015). The data set was univariate normal with a maximum skewness of -1.14 (as expected, all items were negatively skewed) and a maximum kurtosis of 1.3.

Given that the univariate normality was confirmed for each measurement item, the data set was tested for multivariate normality. Assessment for normality was conducted using SPSS AMOS 23. Mardia's coefficient of multivariate kurtosis and its normalised score (z-score) were 115.939 and 9.962. Normalised coefficients above 3 point toward non-normality (Mardia 1970, 1974). Given that the normalised coefficient (9.962) is clear of the tolerance level (3), the sample was regarded as multivariate non-normal. In ML estimation, non-normality makes merely negligible deviations to parameter estimates, and has no real effect on the standard errors of estimates under medium non-normality (Lei & Lomax 2005). Moreover, it is impossible to accomplish multivariate non-normality in actuality (Lei & Lomax 2005).

Deleting outliers is one approach in dealing with non-normal data (Kline 2015). However, the generalisability of the results will be reduced by the deletion of the outliers. If the outliers genuinely represent the sample population, keeping the outliers is recommended. Nonetheless, the univariate and multivariate outliers influence the factor solution (Tabachnick & Fidel 2013). Thus, Mahalanobis distance was used to isolate the outliers. AMOS estimates of Mahalanobis distance is not so reliable in this case as it assumes that the data is multivariate normal (Blunch 2012). Hence, Mahalanobis distances were calculated using SPSS 23. To locate outliers, the calculated values were compared against the critical value of chi-square (x^2) distribution. Consequently, the critical value of x^2 distribution at the probability of $p = 0.001$ for the 61 variables in the data set was 100.28. The cases where Mahalanobis distance was larger than the critical value were identified as outliers (Tabachnick & Fidel 2013). There were 2 such cases of outliers representing less than 1% of cases in the sample of 227. Removal of the 2 outliers produced Mardia's coefficient of multivariate kurtosis and its normalised score (z-score) of 98.459 and 8.423 respectively. The normalised coefficient was not much decreased, implying the sample was still multivariate non-normal.

Due to its smaller proportion of representation and effect, and the outliers seem to truly represent the population, it was decided to retain the outliers in the data set for further testing (Hair et al. 2014). Therefore, the sample size remained at 227.

All responses represented individual retailers without any repetition or duplication. It was ensured that no multiple cases were collected from the same firm as the survey online link was sent exclusively to a single contact of the retail firm. Ultimately a sample of 227 cases was progressed for the statistical analysis.

5.2.4 Sample size

Some statistical algorithms utilised in structural equation modeling (SEM) are unreliable with smaller samples (Hair et al. 2014). Therefore, the sample size is important in SEM. Also, a larger sample size intensifies statistical capacity by moderating sampling error (Bollen & Stine 1992; Byrne 2013; Hair et al. 2014). Soni and Kodali (2012) claim that multivariate analysis technique such as SEM needs a minimum of 200 cases or a response to the variable ratio of 10:1. Having 15 respondents per study construct is generally acceptable to counter problems of multivariate non-normality (Hair et al. 2014). A sample of over 200 can provide a decent base for ML estimation (Hair et al. 2014). While a sample of 150 cases is sufficient for a convergent and appropriate solution (Anderson & Gerbing 1984). A minimum of 150 cases is recommended for SEM for models with seven or fewer constructs (Hair et al. 2014). With non-normal data, a minimum of 100 cases is capable enough in providing accurate parameter estimates in SEM (Lei & Lomax 2005). Therefore, the sample of 227 cases was deemed enough for SEM analysis of this study.

5.3 Sample characteristics

The majority of the 227 respondent organisations were large. The Australian Bureau of Statistics (ABS) (ABS_ANZSIC 2013) classifies organisations that employ fewer than 20 employees as small, those that employ 20–199 as medium and those that employ more than 200 as large organisations. Based on ABS classifications, the sample consisted of 49.8% (n=113) large organisations, 45.8% (n=104) medium-sized organisations and only 4.4% (n=10) small organisations. Chart 5.1 represents the breakdown of organisation sizes of respondent organisations evaluated by the number of employees.

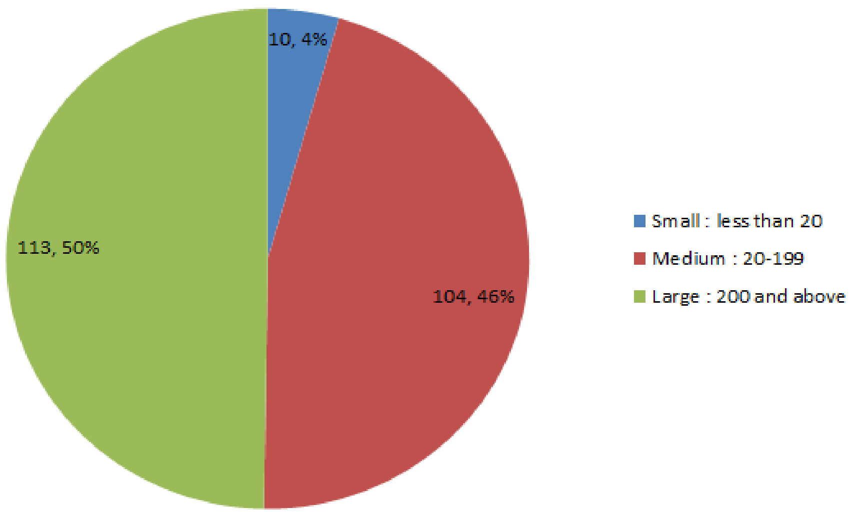


Chart 5.1 The breakdown of organisation sizes of respondent organisations.

The respondents were probed on the geographic scope of their supply chain. The majority identified the extent of their supply chain as worldwide. The breakdown of the geographic scopes of the respondent's supply chain networks was local (only within Australia) 14.1% (n=32), regional (only within Australia and Asia Pacific) 30% (n=68) and worldwide 55.8% (127). Chart 5.2 represents the dissection of the geographic scopes of respondents supply chain networks.

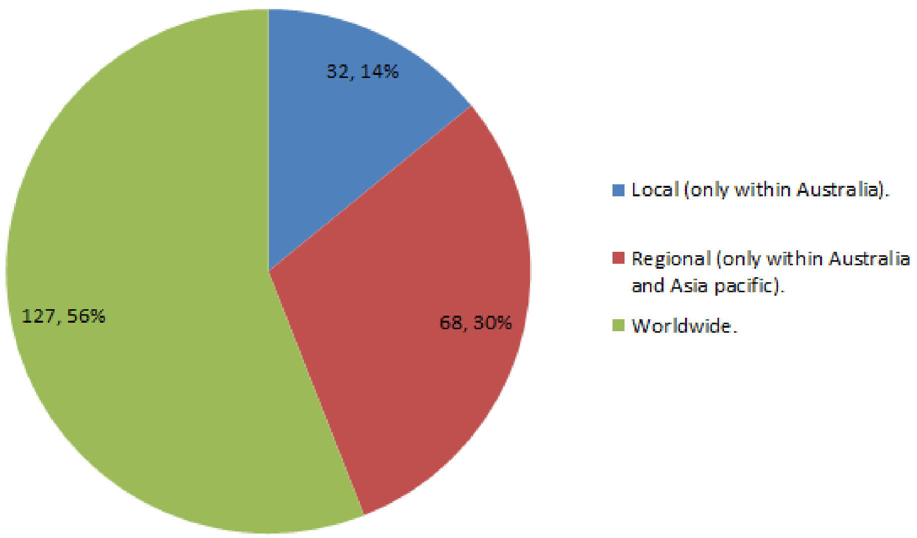


Chart 5.2 The dissection of the geographic scopes of respondents supply chain networks.

Out of the respondents, 56.8% (n=129) disclosed that they consider their organisation to belong to traditional store-based walk-in model (bricks and mortar), while only 4.4% (n=10) belonged to an online sales model (e-tail). However, 38.8% (n=88) of the sample consider themselves to have multi-channel sales model (both), uncovering the emergence of the neoteric conjoined form in retail. The breakdown of retail forms of respondent organisations is displayed in Chart 5.3.

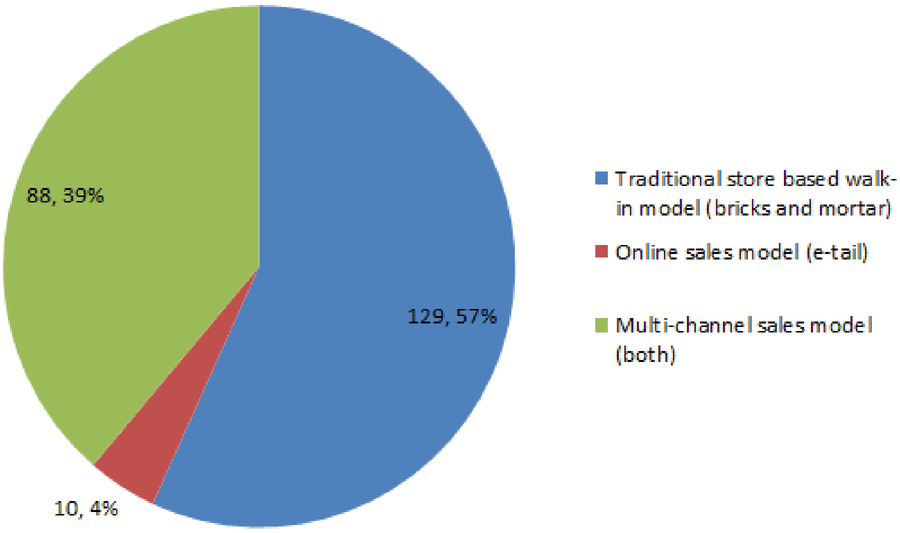


Chart 5.3 The breakdown of retail forms of respondent organisations

The retail sector/group of respondent organisations included all ANZSIC subdevisions. The highest portion of respondents belonged to supermarkets or the grocery sector (n=37), followed by clothing, footwear and personal accessories (n=33). 22 respondents belonged to the others category which included toy stores (2), liquor stores (2), recreational goods stores (2), sport, camping and outdoors stores (2), a discount variety store, an office accessories store, a fresh fruit and vegetable store, a building/hardware/outdoor store, a designer jewellery and accessories shop, a specialty pet food shop, a camera shop, a party supplier and a firearm store. The breakdown of the retail group/nature of respondent organisations is presented in Chart 5.4.

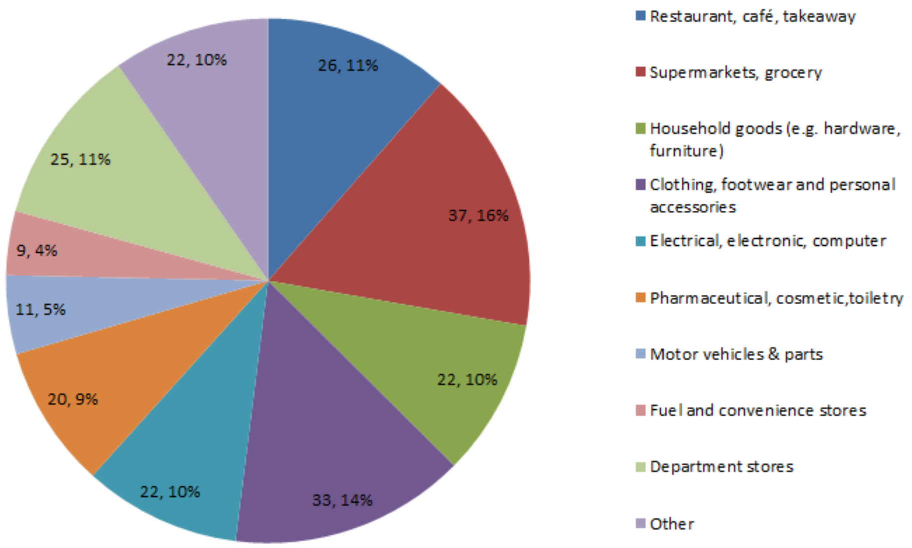
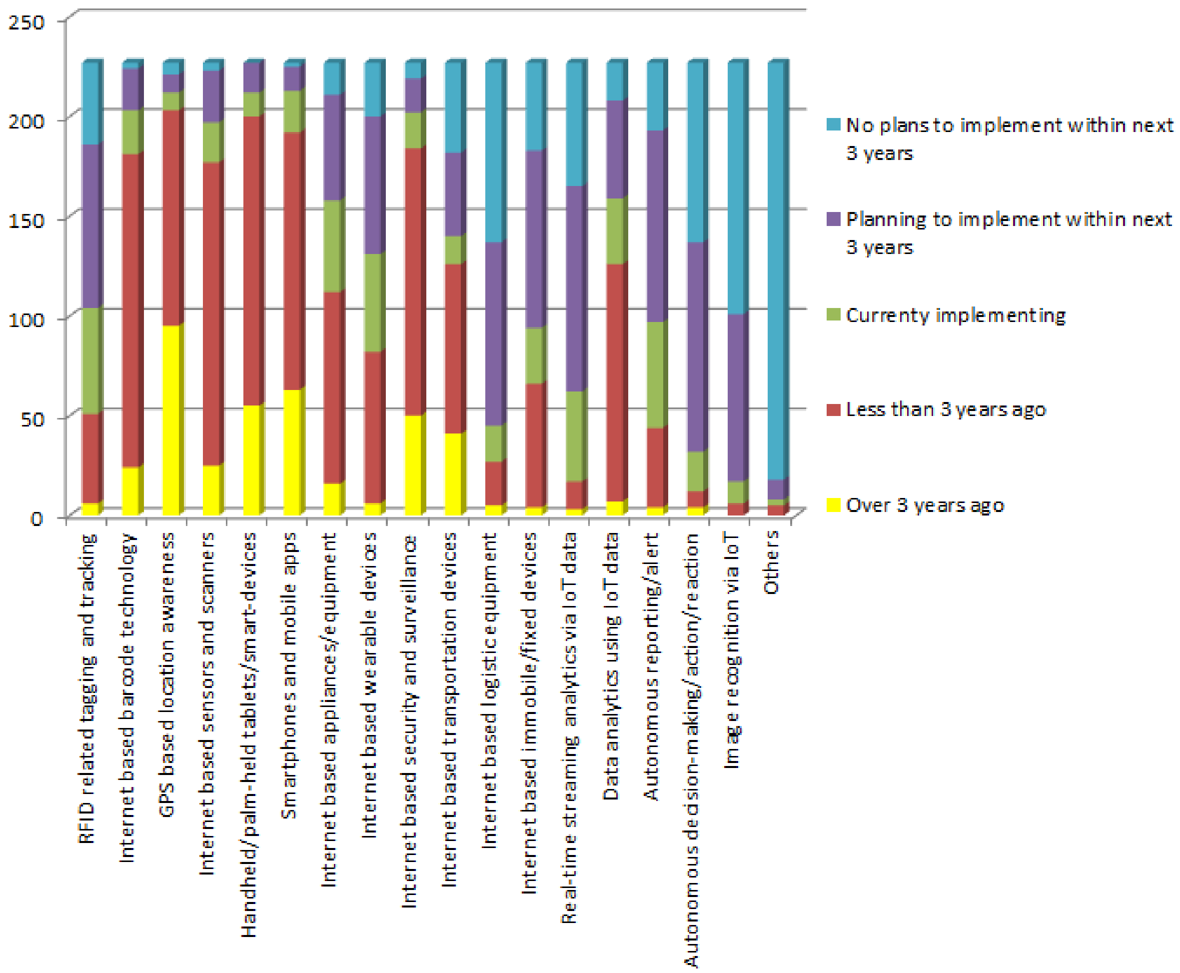


Chart 5.4 The breakdown of the retail sector of respondent organisations

The sample looks well rounded with representation for various sizes, forms and natures of retail organisations.

Each respondent was queried on what forms of IoT were currently deployed in their supply chains and what forms are planned to be implemented in the near future with time frames. Graph 5.1 displays how the respondents have implemented or envisage implementing each form of IoT in their supply chain operations.

Even though RFID is the primary form of IoT, the use of RFID related tagging and tracking is trivial. On the other hand, Internet-based barcode technology, GPS-based location awareness, Internet-based sensors and scanners, handheld/palm-held tablets/smart devices, smartphones and mobile apps and Internet-based security and surveillance display a high concentration of deployment. The finding confirms that, although IoT originated with RFID, it is now a central element on its own, with far-reaching capabilities and eclectic diffusion.

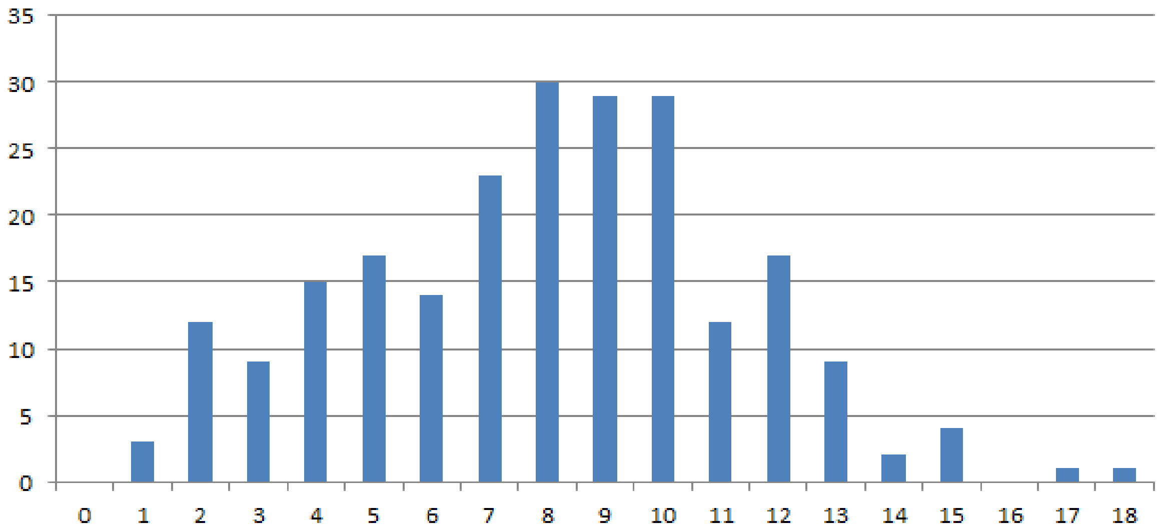


Graph 5.1 The timeframe for current/planned implementation of each form of IoT in respondents' supply chain operations.

Out of the 227 respondent organisations, every single one had at least one form of IoT currently deployed within their supply chain operations. While 89% (n=203) of respondents had four or more forms, 33% (n=75) respondents had ten or more IoT forms currently deployed in their respective supply chain operations. These statistics confirm the diffusion of IoT in many forms in retail supply chains in Australia. It also endorses the suitability of the sample in term of respondents' familiarity with IoT technology and their ability to provide their perceptions of its performance outcomes. The number of organisations against each number of IoT forms currently deployed in their supply chain is displayed in Table 5.1. Graph 5.2 shows the number of organisations against the number of IoT forms currently deployed in their supply chain operations.

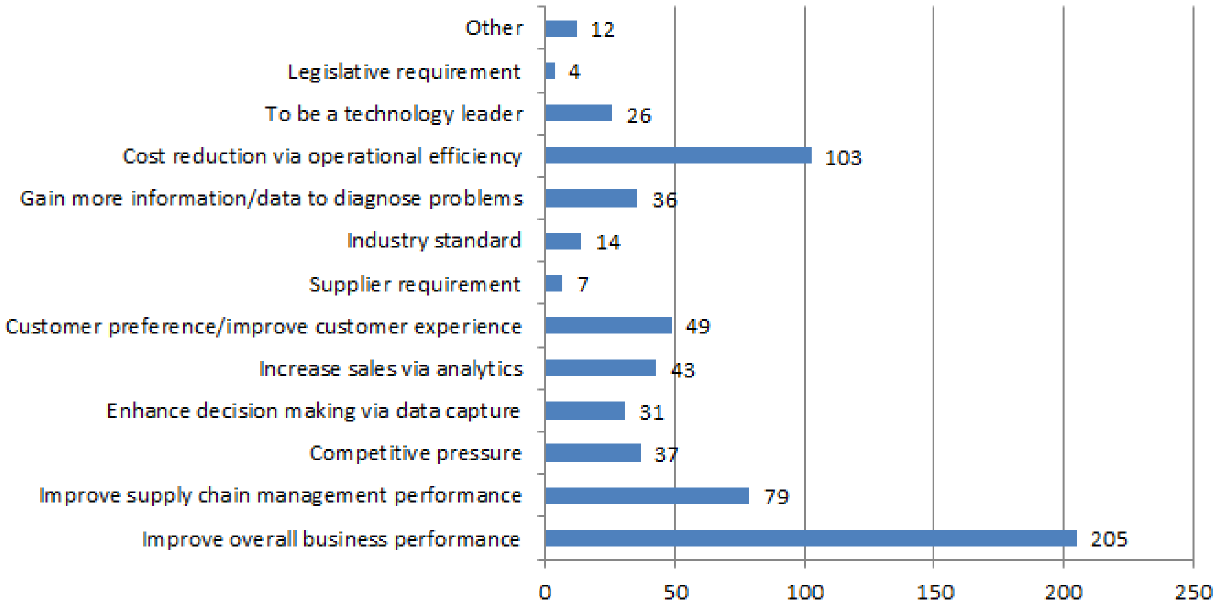
Table 5.1 The number of deployed IoT forms (in their supply chain operations) vs number of firms.

No of IoT forms	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
No of firms	0	3	12	9	15	17	14	23	30	29	29	12	17	9	2	4	0	1	1



Graph 5.2 The number of deployed IoT forms (in their supply chain operations) vs number of firms.

When asked what influenced IoT adoption in their organisation's supply chain operations (provided the choice of picking more than one answer), the overwhelming majority (n=205, 90%) nominated ‘improve overall business performance’ as the key motive. The study hypothesis H4a will be validated if that is the case in reality. That was followed by cost reduction via operational efficiency (n=103, 45%) and to improve supply chain management performance (n=79, 35%). The organisations’ motives for the adoption of IoT in their supply chain operations (more than one answer allowed) is presented in Graph 5.3.



Graph 5.3 The organisations' motives for the adoption of IoT in their supply chain operations

Various characteristics of the respondents were also queried to assess the respondents' suitability for the study. They were asked how long they have been working in the current organisation. Out of 227 respondents, 218 of them had over 2 years of experience with their respective organisation to develop sufficient know-how of the company. Most (32%) were within 2 to 4 years of being with the organisation, followed by respondents with 5 to 6 years of experience in the organisation (20%). Chart 5.5 represents the categorisation of respondents' work experience in their respective organisations.

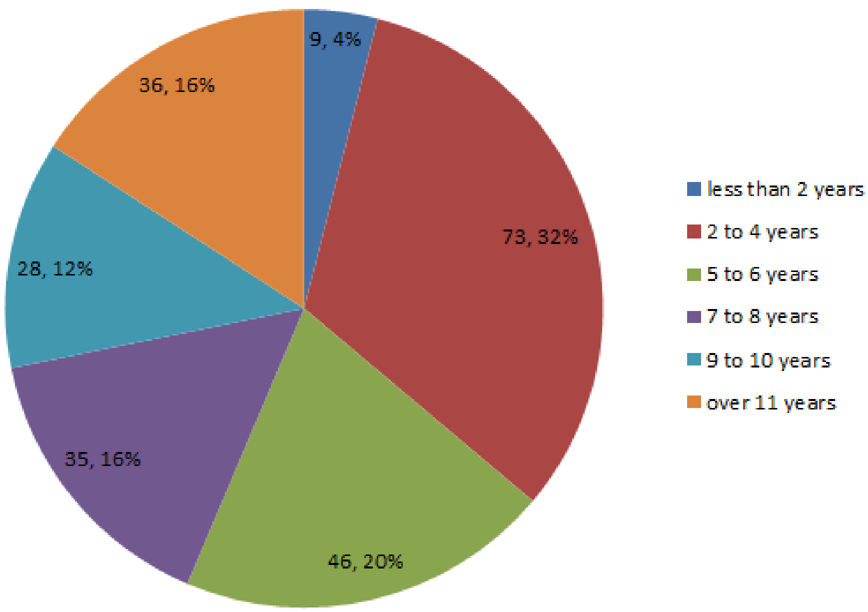


Chart 5.5 The categorisation of respondents' length of work experience in their respective organisations.

All of the survey respondents were managers or above in their organisation except for 1 staffer with over 2 years of experience in the company. As the study was only sent to managers, the assumption was that a manager had delegated and entrusted the task to a staffer with the ideal expertise to answer the questionnaire or a manager mistakenly selected the wrong option. The sample consisted of responses mainly by the categories of CEO/Chairmen/MD//Director/General Manager (n=34, 15%), Operations/Supply Chain/Logistics manager (n=55, 24.2%), Middle management (n=65, 28.6%) (The middle management category allowed to distinguish managers who do not hold specific posts of Operations/Supply Chain/Logistics or IT manager), IT manager (n=60, 26.4%) and Others (n=12, 5.3%) which consisted of 6 store managers, 2 owners, an area manager, a commercial manager, a customer relationship manager and a warehouse manager. This confirms their suitability to provide technology-related supply chain insight and also the success of researchers' efforts to reach study appropriate respondents. Chart 5.6 represents the dissection of job designations of those surveyed.

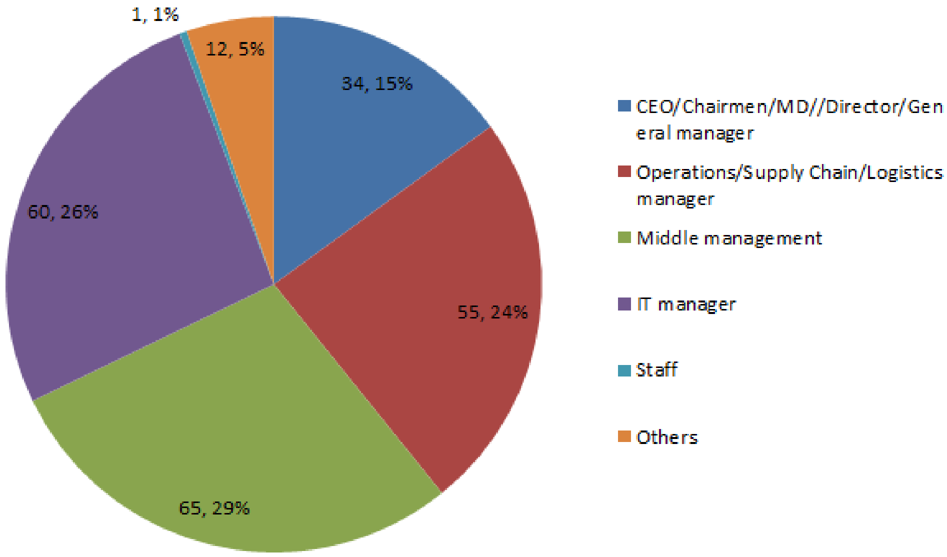


Chart 5.6 The dissection of those surveyed job designations.

Thereafter, the respondents were queried for their level of involvement in strategic decision-making on the supply chain operations of their organisations. Over 62% of the respondents believed that they were top-level decision makers, while only 2.2% thought that their involvement in decision-making was to a slight degree. The above statistic confirms that the sample predominantly consists of perceptions from leading supply chain decision makers. Chart 5.7 classifies the respondent's level of involvement in strategic decision-making on supply chain operations in their organisations.

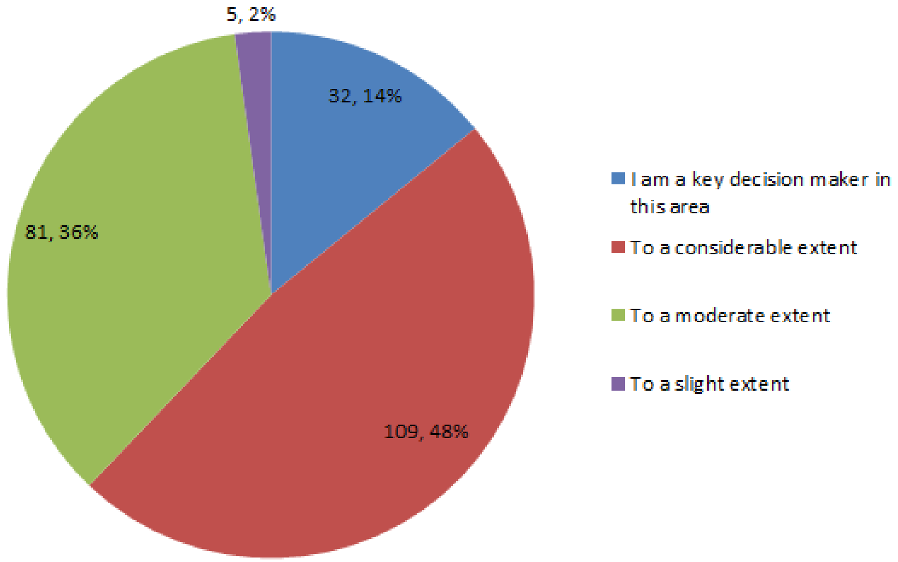


Chart 5.7 Classification of the respondent's level of involvement in strategic decision-making on supply chain operations in their organisations.

As argued with the assistance of descriptive statistics, the sample represents the technology-enabled supply chain know-how of principally top level, experienced operatives of various natures of retail organisations with at least a minimum level of IoT application and awareness. This sample is, therefore, suitable to represent Australian retail industry and its supply chain operations.

5.4 Descriptive statistics

The descriptive statistical data on the demographics of the sample is listed in Table 5:2. The majority (49.8%) of the respondent organisations were large under ABS classification (ABS Counts of Australian Businesses 2017), and the most (55.8%) of their supply chains extend worldwide. Out of 227 cases, 56.8% of the organisations practice the traditional store-based walk-in model (bricks and mortar). There was a good mix of retail businesses and the highest portion was from supermarkets or grocery with 16%, followed by clothing, footwear and personal accessories with 14%. Overwarming 96% of respondents had over 2 years of experience with their respective organisations, with all but one respondent being managers or above. Out of the sample population, 62% believed that they were top level decision makers.

Table 5.2 Demographic profile of surveyed organisations

Demographic information	**Frequency**	**%**
Firm size		
Small: less than 20	10	4.4
Medium: 20-199	104	45.8
Large: 200 and above	113	49.8
Total	227	100.0
Supply chain scope		
Local (only within Australia).	32	14.1
Regional (only within Australia and Asia Pacific).	68	30.0
Worldwide.	127	55.9
Total	227	100.0
Retail form		
Traditional store based walk-in model (bricks and mortar)	129	56.8
Online sales model (e-tail)	10	4.4
Multi-channel sales model (both)	88	38.8
Total	227	100.0
Retail nature/group		
Restaurant, café, takeaway - ANZSIC Subdivision 41	26	11.5
Supermarkets, grocery - ANZSIC Subdivision 42	37	16.3
Household goods (e.g. hardware, furniture) - ANZSIC Sd 42	22	9.7
Clothing, footwear and personal accessories- ANZSIC Sd 42	33	14.5
Electrical, electronic, computer- ANZSIC Subdivision 42	22	9.7
Pharmaceutical, cosmetic, toiletry- ANZSIC Subdivision 42	20	8.8
Motor vehicles & parts - ANZSIC Subdivision 39	11	4.8
Fuel and convenience stores - ANZSIC Subdivision 40	9	4.0
Department stores- ANZSIC Subdivision 42	25	11.0
Other- ANZSIC Subdivision 42	22	9.7
Total	227	100.0
Respondents experience in the organisation		
less than 2 years	9	4.0
2 to 4 years	73	32.2
5 to 6 years	46	20.3
7 to 8 years	35	15.4
9 to 10 years	28	12.3
over 11 years	36	15.9
Total	227	100.0
Respondents job designation		
CEO/Chairmen/MD//Director/General Manager	34	15.0
Operations/Supply Chain/Logistics Manager	55	24.2

Middle management	65	28.6
IT manager	60	26.4
Staff	1	0.4
Others	12	5.3
Total	227	100.0
Respondents involvement in strategic decision making		
I am a key decision maker in this area	32	14.1
To a considerable extent	109	48.0
To a moderate extent	81	35.7
To a slight extent	5	2.2
Total	227	100.0

The descriptive statistics of the manifest variables by measures of central tendency and dispersion tested using SPSS 23 are displayed in Table 5.3. The scale value of 1 represents the least favourable agreement with the manifest variable, while 7 indicates the most favourable agreement. Mean values of all manifest variables were higher than the midpoint (between 5.48 to 4.05) except for variables Q4_5, Q4_6 and Q5_8 which produced means of 3.88, 3.586 and 3.877 respectively.

Table 5.3 The Mean and SD of manifest variables

Item no	Measure	Mean	Std. dev.
IoT capability			
Q4_1	To provide individual item level identification.	4.802	1.370
Q4_2	To provide unit level (product group/pallet) identification.	4.903	1.237
Q4_3	To monitor, track and trace supply chain entities and people through auto-captured data.	4.608	1.252
Q4_4	To measure supply chain activities, processes and its environmental conditions.	4.502	1.381
Q4_5	To help control supply chain processes remotely.	4.445	1.287
Q4_6	To make autonomous supply chain decisions.	3.881	1.457
Q4_7	To provide real-time information to optimise supply chain activities	5.075	1.289
Q4_8	To provide real-time intelligence of supply chain operations.	3.586	1.477
Q4_9	To provide large volumes and variety of data to apply data analytics for tactical and strategic decision making.	4.890	1.156
Q4_10	To strengthen inter and intra-organisational information sharing within the supply chain.	5.339	1.308
Q4_11	To facilitate inter and intra-organisational decision making within the supply chain.	4.674	1.201
Q4_12	To strengthen communication and coordination between operators.	4.934	1.259
Supplier integration			
Q5_1	Improve information exchange with our suppliers.	4.881	1.237
Q5_2	Establish a quick ordering of inventory from our suppliers.	4.634	1.321
Q5_3	Accurately plan and adopt the procurement process in collaboration with our suppliers.	4.736	1.418

Q5_4	Stabilise procurement with our suppliers.	4.511	1.381
Q5_5	Share real-time demand forecasts with our suppliers.	4.590	1.450
Q5_6	Improve strategic partnerships with our suppliers.	4.612	1.327
Q5_7	Help our suppliers improve their processes to better meet our needs.	4.687	1.281
Q5_8	Improve the account payable processes for suppliers.	3.877	1.512
Q5_9	Improve the transport/logistics processes for logistics partners to deliver orders just in time.	5.480	1.260
Q5_10	Improve our receiving processes for delivered goods.	4.388	1.334
Internal integration			
Q6_1	Improve the integration of data among internal functions.	4.722	1.166
Q6_2	Improve real-time communication and linkage among all internal functions.	4.705	1.329
Q6_3	Accurately plan and adopt internal processes in collaboration with cross functional teams.	4.502	1.415
Q6_4	Make and adopt demand forecasts in collaboration with cross functional teams.	4.573	1.441
Q6_5	Improve inventory management in collaboration with cross functional teams.	4.564	1.350
Q6_6	Improve real-time searching of the inventory levels.	4.480	1.371
Q6_7	Improve real-time searching of logistics-related operating data.	4.705	1.302
Q6_8	Employ cross functional teams in process improvement.	4.141	1.469
Q6_9	Improve replenishment of shop floor shelves.	4.485	1.263
Q6_10	Reduce stock outs in the shop floor shelves.	4.410	1.332
Customer integration			
Q8_1	Improve the strength of linkages with our customers.	4.850	1.288
Q8_2	Improve regular contacts with our customers.	4.441	1.402
Q8_3	Improve communication with our customers on products and promotions.	4.260	1.333
Q8_4	Make and adopt demand forecasts with a real-time understanding of market trends.	4.696	1.481
Q8_5	Improve the customer shopping experience/time/ordering/customising processes.	4.608	1.418
Q8_6	Accurately plan and adopt the checkout/dispatch/delivery processes through a better understanding of market trends.	4.855	1.262
Q8_7	Improve the check-out/dispatch/delivery process of goods.	4.991	1.152
Q8_8	Improve and simplify the payment receivable process from our customers.	4.595	1.274
Q8_9	Improve our customer feedback process.	4.075	1.531
Supply chain performance			
Q9_1	Improve product quality.	4.053	1.444
Q9_2	Improve supply chain delivery reliability.	4.696	1.357
Q9_3	Improve fill rates.	4.656	1.404
Q9_4	Improve perfect order fulfilment (deliveries with no errors).	4.899	1.552
Q9_5	Improve supply chain flexibility (react to product changes, volume, mix).	5.079	1.476
Q9_6	Reduce the cash-to-cash cycle time.	4.216	1.479
Q9_7	Reduce the total supply chain management cost.	4.581	1.617
Q9_8	Reduce the cost of goods sold.	4.119	1.204
Q9_9	Improve value-added productivity (sales per employee).	4.916	1.490
Firm performance			
Q10_1	Improve the product delivery cycle time.	4.238	1.329
Q10_2	Improve productivity (e.g. assets, operating costs, labour costs).	4.758	1.372
Q10_3	Improve sales of existing products.	4.705	1.309
Q10_4	Find new revenue streams (e.g. new products, new markets).	4.084	1.548

Q10_5	Building strong and continuous bonds with customers.	4.304	1.493
Q10_6	Gaining precise knowledge of customer buying patterns.	4.727	1.444
Q10_7	Improve customer satisfaction.	4.330	1.392
Q10_8	Improve employee satisfaction.	4.194	1.385
Q10_9	Improve employee health and safety.	4.352	1.379
Q10_10	Reduce energy use.	4.388	1.560
Q10_11	Improve return/re-use/recycle.	4.458	1.370

The majority of the mean values measured over the mid-point (4) of the measurement scale pointing to the presence of the characteristics measured by manifest variables. The values distributed around the mean, indicate that the sample is suitable for further analysis.

The lower values of the middle point for the variables Q4_5 and Q4_6 reflected that the majority of the organisations do not believe that IoT currently has the capability to make autonomous supply chain decisions or provide real-time intelligence for supply chain operations. Likewise, the majority of the respondents do not feel that IoT assists to improve their account payable processes for suppliers. Conversely, they consider strengthening inter- and intra-firm information sharing within the supply chain as the topmost IoT capability. Likewise, the improvement of the transport/logistics processes for logistics partners to deliver orders just in time, improved integration of data among internal functions and improved check-out/dispatch/delivery process of goods were the topmost supplier integration, internal integration and customer integration competency improvements respectively. Organisations believe that their highest improved attribute in supply chain context is supply chain flexibility (reacting to product changes, volume, mix) while improving productivity (assets, operating costs, labour costs) was considered the highest improved firm performance attribute.

5.5 The Measurement Model

Once the suitability of the data for the conduct of multivariate statistical analysis was confirmed, the next step was to apply the procedures for SEM. The measurement models for each construct were confirmed at first. To do so, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) was conducted in succession on each latent variable to assess the suitability of their measurement items. The final dataset of 227 cases was the sample used to perform EFA and CFA (Huo 2012; Yu 2015). It is suggested that conducting an EFA is not required when adopting a valid and reliable measurement scale or a questionnaire from the existing literature (Netemeyer et al. 2003). However, since the questionnaire was applied to a different industry context, and also some of the measurement items were newly introduced (including all the items for IoT capability) and most were modified to suit the study context and the requirement, it was decided to apply EFA to identify the underlying structure between measured variables (Byrne 2013; Hair et al. 2014). EFA helps to establish how well the observed variables are linked to their underlying factors (Byrne 2013). While EFA explores the data and provides information on how many factors can best represent the data, CFA tests how well the measured variables represent its conforming constructs (Hair et al. 2014). Therefore CFA was subsequently used to confirm the relationship between observed variables and their underlying factors (Byrne 2013).

The minimum sample size required to deliver reasonable answers in an EFA is about 100 cases or ten observations per the number of variables analysed (Hair et al. 2014). Likewise, when ML estimation is applied, a sample of at least 100 cases is necessary to derive reliable answers from a CFA (Anderson & Gerbing 1984). As per the classical measurement theory, the measurements of a construct are uni-dimensional (DeVellis 2016). Therefore, the measurement models of each construct were independently examined for its uni-dimensionality in advance of collectively testing all the constructs in a combined full model. Given that all the measurement items in this study were reflective indicators for each construct, the measurement items for each construct should be unidimensional, in addition to retaining a positive correlation between the items of each construct and maintaining a positive correlation between constructs (Bollen & Lennox 1991). Since the analyses conducted earlier revealed that the data is multivariate non-normal, the Principal Axis Factoring (PAF) procedure was chosen as the most suitable factor extraction method for EFA (Fabrigar et al. 1999; Osborne & Costello 2009). For the same reason, in addition to the global fit indices, Bollen-Stine's bootstrap x^2 test was also performed in CFA to examine the *p*-value (Blunch 2012; Bollen & Stine 1992; Walker & Smith 2016).

The fit indices and their cut-off values deemed appropriate for model evaluation are displayed in Table 5.4. Fit indices were decided on to cover its 3 types: they are absolute, incremental and parsimonious measures. The x statistic, root mean square error of approximation (RMSEA), standardised root mean square residual (SRMR), goodness-of-fit index (GFI) and normed x^2 were examined for the absolute fit measure. Comparative fit index (CFI), normed fit index (NFI) and Tucker-Lewis index (TLI) were selected to measure incremental fit, and the adjusted goodness-of-fit (AGFI) was used for parsimonious (applied to compare models) fit index. Normed x^2 can also be used as a parsimonious fit index (Schumacker & Lomax 2004).

Due to their poor performance in small samples (n < 250), the Goodness-of-fit index (GFI), Adjusted goodness-of-fit (AGFI) and Normed fit index (NFI) were not considered in model evaluation, specifically on the complex combined full model (Hair et al. 2014; Hu & Bentler 1998; Hu & Bentler 1999). GFI and AGFI can be overly influenced by sample size (Fan et al. 1999; Maiti & Mukherjee 1991). NFI underestimates fit in small samples (Iacobucci 2010). Use of the CFI over the NFI is recommended as an index of choice as CFI is an improved version of the NFI (Bentler 1990; Byrne 2013; Hu & Bentler 1999). Therefore, GFI, AGFI and NFI are rarely applied today, in favour of the recent development of far relevant fit indices (Hair et al. 2014). Appropriately, the current literature (Flynn et al. 2010; Huo 2012; Ralston et al. 2015; Wong et al. 2011a; Yu 2015) on similar themes in operations and supply chain management arena have avoided applying the above fit indices.

The pursuit of increasing model fit can lead to poor practices in model specification therefore not a good trade-off; as such reduction of the number of items per construct may compromise the investigation of theory (Hair et al. 2014; Kenny & McCoach 2003; Marsh et al. 1998). In general, 'using 3 to 4 fit indices provides adequate evidence of a model fit' (Hair et al. 2014, p. 583). Using multiple indices of different types and adjusting index cut-off values based on model characteristics is recommended to establish an acceptable fit (Hair et al. 2014). Hair et al. (2014)'s recommended goodness of fit indices for such a model and number of cases are x^2, CFI or TLI, SRMR, RMSEA, which consists of an absolute fit index, an incremental fit index, a goodness of fit index and a badness of fit index.

However, the x^2 is sensitive to sample size and number of indicator variables (Bentler 1990; Gerbing & Anderson 1985). As many factors impact the x^2 significance test that practically any result can be questioned (Hair et al. 2014, p. 582). Furthermore, the applicability of x^2 test in evaluation of model fit has been criticised for its tendency for model rejections, if the data deviates from multivariate normality (Hu et al. 1992; Schumacker & Lomax 2004). The sample was earlier ascertained as multivariate non-normal. Hence, Bollen-Stine bootstrap x^2 test was performed (Bollen & Stine 1992). In a case of less than 250 observed variables and over 30 measurement items, insignificant p-value should not be expected (Hair et al. 2014, p. 584). Bollen-Stine p-value will be considered in that case. However, in a case of less than 250 observed variables if the number of items is less than 12, an insignificant p-value should be expected (Hair et al. 2014, p. 584). Both scenarios were applicable in this study, given that the cognitive measurement models of each construct (<12 items) were tested prior to the assessment the combined complete model (>30 items).

Table 5.4 Model fit indices and the criteria used in the study

Model fit indices	Criteria	Reference
X^2	-	
Df	-	
P	> 0.05	Jöreskog and Sörbom (1982); Hair et al. (2014); Byrne (2013)
Standardised root mean square residual (SRMR)	< 0.08	Hu and Bentler (1999); Hair et al. (2014)
Root mean square error of approximation (RMSEA)	<0.08	Browne and Cudeck (1992); Hair et al. (2014);
Normed fit index (NFI)*	> 0.90	Bentler and Bonett (1980); Byrne (2013)
Comparative fit index (CFI)	> 0.90	Bentler and Bonett (1980); Hu and Bentler (1999); Hair et al. (2014); Byrne (2013)
Goodness-of-fit index (GFI)*	> 0.90	Bentler and Bonett (1980); Hair et al. (2014); Byrne (2013)
Adjusted goodness-of-fit (AGFI)*	> 0.90	Hu and Bentler (1999); Byrne (2013)
Tucker-Lewis index (TLI)	> 0.90	Bentler and Bonett (1980); Hair et al. (2014); Hu and Bentler (1999)
Normed X^2 (X^2/df)	1–2	Bollen (1989); Ullman and Bentler (2003); Larsson, Pousette and Törner (2008)

*** not considered in model evaluation**

5.5.1 Measurement model for IoT capability

Using the calibration sample (n = 227), an EFA was performed with having principal axis factoring as the extraction method and direct oblimin as the rotation method. Small coefficients at the absolute value below 0.3 were suppressed.

There were 66 correlations in total. The results indicated that all the correlations were above 0.3 and also all partial correlations were below 0.7. In addition, the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy was 0.942, during which Bartlett's test of sphericity was significant (x^2 = 1614.48, p < 0.001), implying that the data is passable to perform an EFA.

All items retained communalities above 0.3, with the lowest item communality of 0.410. The revealed item communalities indicated that the represented items are capable of explaining a sufficient degree of variance of the IoT capability construct.

EFA revealed a single-factor solution by generating just one factor having an eigenvalue over 1, and the total variance explained by the single-factor solution was 57.00%. Also, the scree plot demonstrates a well-defined break after the first factor as shown in Figure 5.1. Factor matrix indicated that all the items loaded had values above 0.577. The results confirmed the uni-dimensionality of the measurement items chosen for IoT capability.

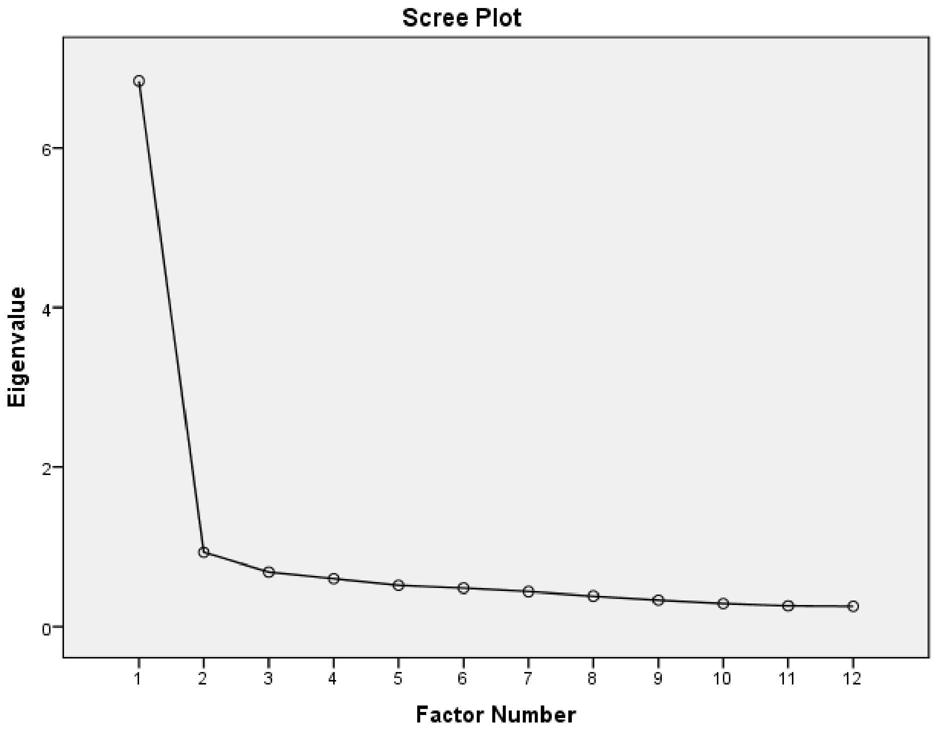


Figure 5.1 Scree plot for eigenvalues on IoT capability

The EFA structure was then validated using CFA (n=227). The results pointed to an inferior model fit with x^2 (54) = 156.033, p = 0.000 and Bollen-Stine p = 0.005. The model fit indices were x^2/df = 2.9, SRMR=0.0470, RMSEA=0.091, NFI=0.905, GFI=0.891, AGFI=0.849, CFI=0.936 and TLI=0.921. Despite the fact the CFI, NFI and SRMR values indicated adequate, the rest of the indices were lower than the threshold.

The modification indices suggested that freeing the path between Q4_6 and Q4_8 can improve the model fit in the resultant model. The standardised residual covariance matrix also indicated a value of 2.531 between the above two items. A value over 2.5 suggests a problem (Hair et al. 2014). A value above 2 suggests the model’s inability to account for the shared variance between items (Jöreskog & Sörbom 1982). Out of the two items, Q4_6 had the least squared multiple correlation and standardised loadings than Q4_8 (Q4_6 = 0.319, 0.564; Q4_8 = 0.371, 0.609 respectively). Modification indices also revealed that Q4_6 has higher covariance instances with other items than any other measurement item for IoT capability. Therefore, the item Q4_6 was detached from the model.

As a result, the model fit indices were improved, but the improvement was not enough for a model fit. By reiterating the same routine/procedure to drop the first item of the model, the measurement items Q4_12, Q4_1 and Q4_11 were also respectively identified as unfitting, and therefore were dropped in that order to fit the IoT capability measurement model.

The consequential adaptation demonstrated a good model fit with x^2 (20) = 29.789, p=0.073 and Bollen-Stine p=0.144, x^2/df=1.489, SRMR=0.0266, RMSEA=0.047, NFI=0.969, GFI=0.967, AGFI=0.941, CFI=0.990 and TLI=0.985. Factor loadings were significant ($p < 0.001$) and were between 0.594 to 0.808.

The measurement model for IoT capability is displayed in Figure 5.2. The outcomes of the EFA and CFA for the measurement model for IoT capability are displayed in Table 5.5.

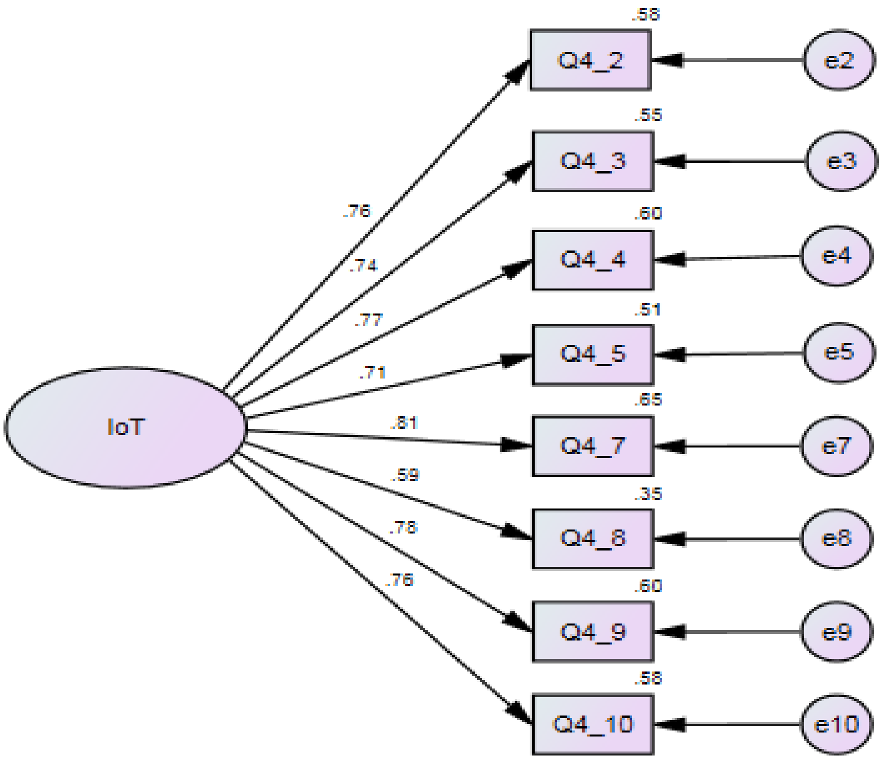


Figure 5.2 Measurement model for IoT capability

Table 5.5 Factor analysis of IoT capability items

Item no	Item Description	EFA Loading	EFA Variance explained	CFA SFL	CFA t-value	CFA SMC
Q4_1	To provide individual item level identification.	0.669	57.00%	Item dropped in CFA		
Q4_2	To provide unit level (product group/pallet) identification.	0.779		0.764	a	0.583
Q4_3	To monitor, track and trace supply chain entities and people through auto-captured data.	0.732		0.744	11.487*	0.554
Q4_4	To measure supply chain activities, processes and its environmental conditions.	0.770		0.774	12.016*	0.599
Q4_5	To help control supply chain processes remotely.	0.705		0.715	10.968*	0.511
Q4_6	To make autonomous supply chain decisions.	0.577		Item dropped in CFA		
Q4_7	To provide real-time information to optimise supply chain activities	0.799		0.808	12.626*	0.653
Q4_8	To provide real-time intelligence of supply chain operations.	0.620		0.594	8.922*	0.352
Q4_9	To provide large volumes and variety of data to apply data analytics for tactical and strategic decision making.	0.788		0.775	12.037*	0.601
Q4_10	To strengthen inter and intra organisational information sharing within the supply chain.	0.743		0.763	11.816*	0.582
Q4_11	To facilitate inter and intra organisational decision making within the supply chain.	0.750		Item dropped in CFA		
Q4_12	To strengthen communication and coordination between operators.	0.783		Item dropped in CFA		

Eigenvalue = 6.839;	*x^2 (20)=29.789, p = 0.073*
KMO =0.942;	x^2/df=1.489, SRMR =0.0266
Bartlett's test of	RMSEA=0.047, NFI=0.969
sphericity:	GFI=0.967, AGFI=0.941
x^2= 1614.476, $p<0.001$	CFI=0.990, TLI=0.985

Note: Adjusted goodness-of-fit (AGFI); CFA=Confirmatory Factor Analysis; CFI=Comparative Fit Index; EFA=Exploratory Factor Analysis; GFI=Goodness-of-Fit Index; KMO=Kaiser-Meyer-Olkin Measure of Sampling Adequacy; Normed fit index (NFI); RMSEA=Root Mean Square Error of Approximation; SMC=Squared Multiple Correlation; SFL=Standardised Factor Loadings; SRMR=Standardised Root Mean Square Residual; TLI=Tucker-Lewis Index;
*p<0.001

5.5.2 Measurement model for supplier integration

Adhering to the same procedure as the earlier instance, using the calibration sample (n = 227), an EFA was performed with having principal axis factoring as the extraction method and direct oblimin as the rotation method. Small coefficients at the absolute value below 0.3 were suppressed.

In this case, there were 45 correlations altogether. The results indicated that all the correlations were above 0.3 and all partial correlations were below 0.7. In addition, the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy was 0.939 together with significant Bartlett's test of sphericity ($x^2 = 1342.42$, $p < 0.001$), demonstrating that the data was fitting to perform an EFA.

All the items had communalities above 0.3 with the lowest being 0.403. The satisfactory item communalities revealed that the chosen items can adequately explain the expanse of the variance of the supplier integration construct.

EFA revealed a single-factor solution by generating a factor greater than the eigenvalue of 1. The total variance explained by the solution was 60.072%.

The scree plot also displays a well-defined break subsequent to the first factor as in Figure 5.3. Factor matrix indicated that all items loaded were at over 0.7, except for Q5_8 that was still loaded at a satisfactory 0.572 factor loading. Therefore, the results confirmed the uni-dimensionality of the measurement items of supplier integration.

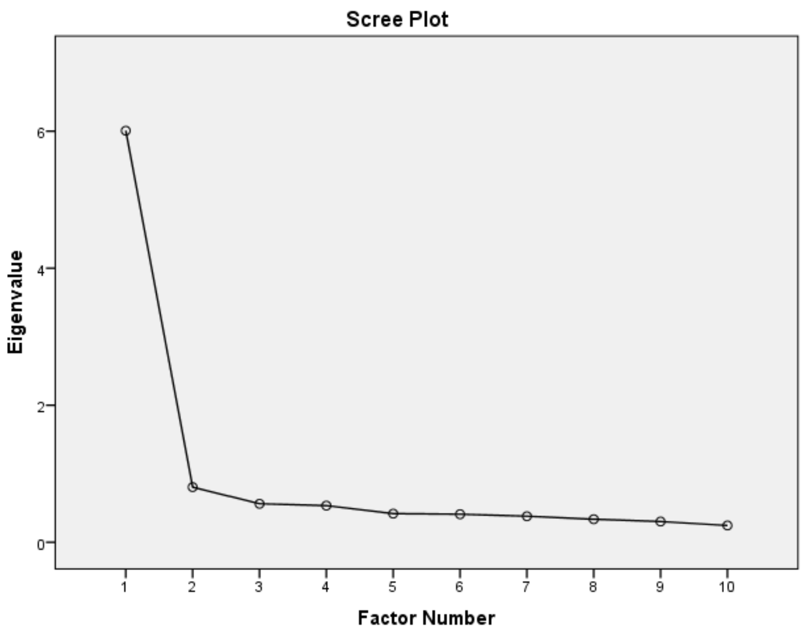


Figure 5.3 Scree plot for eigenvalues on supplier integration

The EFA structure at that point was validated with the sample of data (n = 227) via CFA. Initial results implied an inferior model fit with x^2 (35) = 88.598, p = 0.000 and Bollen-Stine p = 0.005. The model fit indices were x^2/df=2.531, SRMR=0.0389, RMSEA=0.082, NFI=0.935, GFI=0.926, AGFI=0.883, CFI=0.953 and TLI=0.948. Even though CFI, NFI, GFI, TLI and SRMR values were fitting, the rest of the indices were lower than the threshold values.

As per the modification indices, freeing the path between Q5_8 and Q5_10 could improve the model fit. Also, the standardised residual covariance matrix revealed 1.669 for those items. However, Q5_8 retained an inferior squared multiple correlation and standardised loadings than Q5_10 (Q5_8 = 0.327, 0.572; Q5_10 = 0.581, 0.762, respectively). Modification indices also indicated that Q5_8 has higher covariance instances with other items than any other items in the model. The item Q5_8 was, therefore, dropped from the model.

As a result, the model fit indices were improved, but the improvement was not sufficient for a model fit. Following the same procedure as used in earlier CFA model validations to identify unfitting items, Q5_3 was also dropped.

The consequential model demonstrated a good fitting model with x^2 (20) = 21.425, p=0.371 and Bollen-Stine p=0.517, x^2/df = 1.073, SRMR=0.0230, RMSEA=0.018, NFI=0.979, GFI=0.976, AGFI=0.956, CFI=0.999 and TLI=0.998. Factor loadings were significant (p < 0.001) and were between 0.705 to 0.806.

The measurement model for supplier integration is displayed in Figure 5.4, while the EFA and CFA results for the measurement model for supplier integration are presented in Table 5.6.

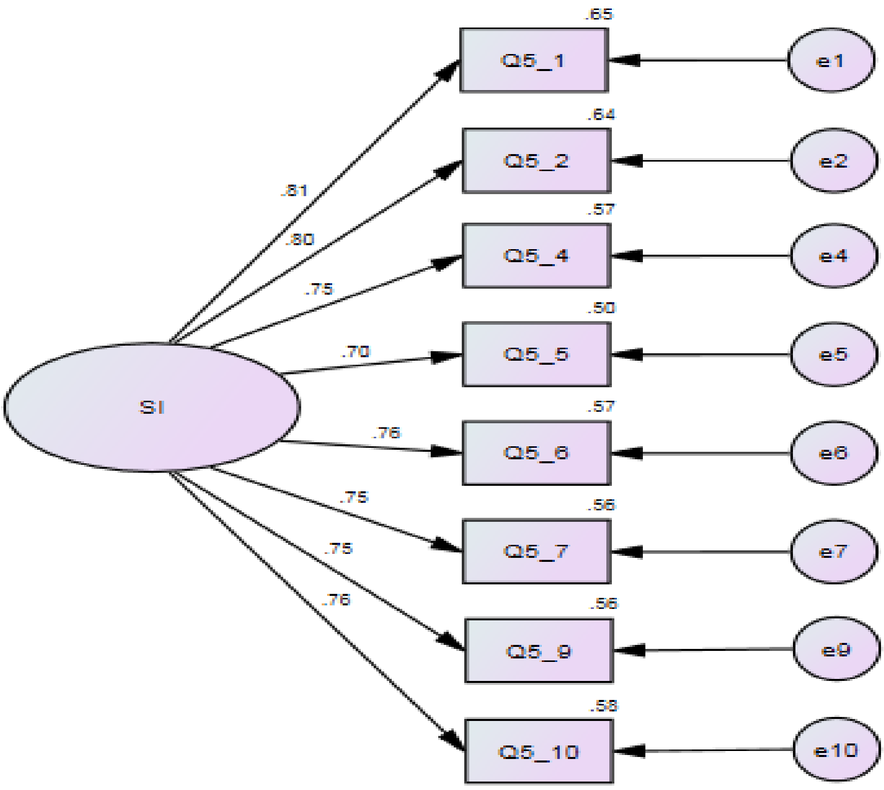


Figure 5.4 Measurement model for supplier integration

Table 5.6 Factor analysis of supplier integration items

Item		**EFA**		**CFA**		
Item no	**Item Description**	**Loading**	**Variance explained**	**SFL**	**t-value**	**SMC**
Q5_1	Improve information exchange with our suppliers.	0.775	60.07%	0.806	a	0.65
Q5_2	Establish a quick ordering of inventory from our suppliers.	0.791		0.803	13.521*	0.644
Q5_3	Accurately plan and adopt the procurement process in collaboration with our suppliers.	0.801		Item dropped in CFA		
Q5_4	Stabilise procurement with our suppliers.	0.780		0.752	12.413*	0.566
Q5_5	Share real-time demand forecasts with our suppliers.	0.712		0.705	11.417*	0.497
Q5_6	Improve strategic partnerships with our suppliers.	0.772		0.756	12.5*	0.572

tm	Help our suppliers improve their processes to better meet our needs.	0.735		0.746	12.28*	0.557
Q5_8	Improve the account payable processes for suppliers.	0.572		Item dropped in CFA		
Q5_9	Improve the transport/logistics processes for logistics partners to deliver orders just in time.	0.734		0.751	12.383*	0.564
Q5_10	Improve our receiving processes for delivered goods.	0.770		0.758	12.542*	0.575
		Eigenvalue = 6.007; KMO =0.939; Bartlett's test of sphericity: x^2= 1342.42, p<0.001		*x^2 (20) = 21.425, p = 0.371* x^2/df=1.073, SRMR =0.0230 RMSEA=0.018, NFI=0.979 GFI=0.976, AGFI=0.956 CFI=0.999 and TLI=0.998		

Note: Adjusted goodness-of-fit (AGFI); CFA=Confirmatory Factor Analysis; CFI=Comparative Fit Index; EFA=Exploratory Factor Analysis; GFI=Goodness-of-Fit Index; KMO=Kaiser-Meyer-Olkin Measure of Sampling Adequacy; Normed fit index (NFI); RMSEA=Root Mean Square Error of Approximation; SMC=Squared Multiple Correlation; SFL=Standardised Factor Loadings; SRMR=Standardised Root Mean Square Residual; TLI=Tucker-Lewis Index;
*p<0.001

5.5.3 Measurement model for internal integration

As with the earlier constructs, using the calibration sample (n = 227), an EFA was performed with having principal axis factoring as the extraction method and direct oblimin as the rotation method. Small coefficients at the absolute value below 0.3 were suppressed.

In this case, there were 45 correlations altogether. The results indicated that all correlations were higher than 0.3, while all partial correlations were below 0.7. The result for the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy was 0. 0.955, even as Bartlett's test of sphericity was significant (x^2 = 1542.049, p < 0.001), demonstrating that the data was fitting to perform an EFA.

Communalities of all the items were above 0.3, with the lowest exhibiting a communality of 0.474. The item communalities revealed that the items can explain an adequate variance of the internal integration construct.

EFA revealed a single-factor solution by generating a factor with a greater eigenvalue than 1. 64.71% of the total variance was explained by the factor. The scree plot also displays a well-defined break subsequent to the first factor as shown in Figure 5.5. Factor matrix indicated that all the items loaded had values above 0.7. The results confirmed the uni-dimensionality of the measurement items of internal integration.

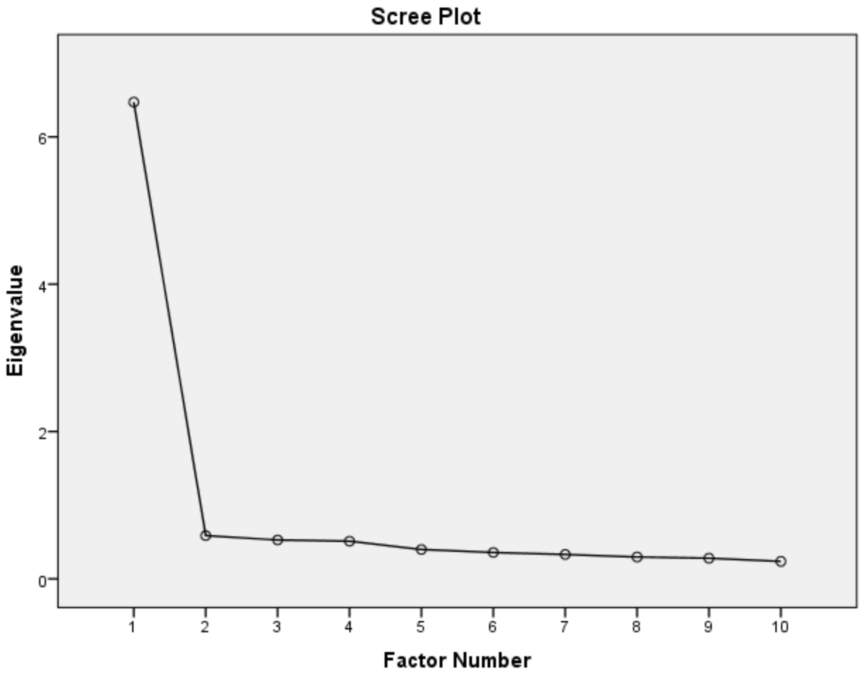


Figure 5.5 Scree plot for eigenvalues on internal integration

The resulting EFA structure was later validated (n = 227) via CFA. An inferior model fit at x^2 (35) = 59.506, p = 0.006 and Bollen-Stine p = 0.075 was indicated. The model fit indices were x^2/df=1.7, SRMR=0.0276, RMSEA=0.056, NFI=0.962, GFI=0.948, AGFI=0.918, CFI=0.984 and TLI=0.979. Even though all fit indices reached acceptable levels, the p-value was below the tolerance level (p>0.5) for a model with less than 12 items.

Following the same procedure used earlier to find a model fit, by drawing on of modification indices, standardised residual covariance matrix, squared multiple correlations and standardised loading values to identify susceptible items, items Q6_5 and Q6_1 were respectively dropped from the CFA model.

The consequential model demonstrated a well-fitting model with x^2 (20) = 24.045, p=0.240 and Bollen-Stine p=0.438, x^2/df=1.202, SRMR=0.0208, RMSEA=0.030, NFI=0.979, GFI=0.974, AGFI=0.953, CFI=0.996 and TLI=0.995. Factor loadings were found significant (p < 0.001) and were between 0.701 to 0.821.

The measurement model for internal integration is displayed in Figure 5.6. The EFA and CFA results for the measurement model for internal integration are presented in Table 5.7.

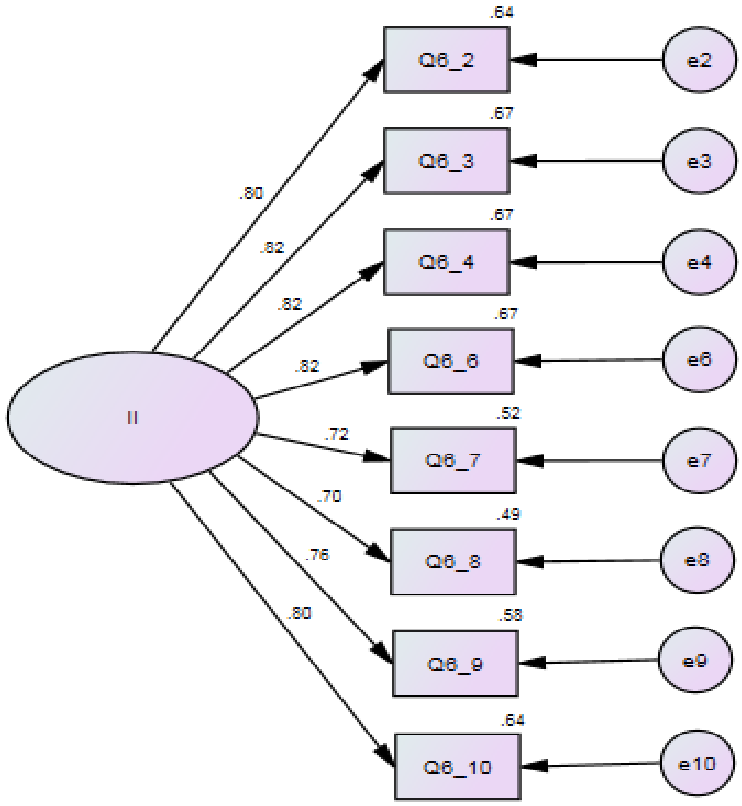


Figure 5.6 Measurement model for internal integration

Table 5.7 Factor analysis of internal integration items

Item		**EFA**		**CFA**		
Item no	**Item Description**	**Loading**	**Variance explained**	**SFL**	**t-value**	**SMC**
Q6_1	Improve the integration of data among internal functions.	0.720	64.71%	Item dropped in CFA		
Q6_2	Improve real-time communication and linkage among all internal functions.	0.802		0.800	a	0.639
Q6_3	Accurately plan and adopt internal processes in collaboration with cross functional teams.	0.816		0.816	13.837*	0.666
Q6_4	Make and adopt demand forecasts in collaboration with cross functional teams.	0.818		0.821	13.957*	0.674
Q6_5	Improve inventory management in collaboration with cross functional teams.	0.824		Item dropped in CFA		

Q6_6	Improve real-time searching of the inventory levels.	0.818		0.821	13.943*	0.673
Q6_7	Improve real-time searching of logistics-related operating data.	0.713		0.718	11.71*	0.516
Q6_8	Employ cross functional teams in process improvement.	0.704		0.701	11.366*	0.492
Q6_9	Improve replenishment of shop floor shelves.	0.782		0.761	12.615*	0.579
Q6_10	Reduce stock outs in the shop floor shelves.	0.791		0.801	13.503*	0.642
		Eigenvalue = 6.471; KMO =0.0.955; Bartlett's test of sphericity: x^2= 1542.049, p<0.001		*x^2 (20) = 24.045, p = 0.240* x^2/df=1.202, SRMR=0.208 RMSEA=0.030, NFI=0.979 GFI=0.974, AGFI=0.953 CFI=0.996 and TLI=0.995		

Note: Adjusted goodness-of-fit (AGFI); CFA=Confirmatory Factor Analysis; CFI=Comparative Fit Index; EFA=Exploratory Factor Analysis; GFI=Goodness-of-Fit Index; KMO=Kaiser-Meyer-Olkin Measure of Sampling Adequacy; Normed fit index (NFI); RMSEA=Root Mean Square Error of Approximation; SMC=Squared Multiple Correlation; SFL=Standardised Factor Loadings; SRMR=Standardised Root Mean Square Residual; TLI=Tucker-Lewis Index;
*p<0.001

5.5.4 Measurement model for customer integration

Using the calibration sample (n = 227), an EFA was performed with having principal axis factoring as the extraction method and direct oblimin as the rotation method. Small coefficients at the absolute value below 0.3 were suppressed.

There were 36 correlations in total. The results indicated that all the correlations were above 0.3 and also, all the partial correlations were below 0.7. Moreover, the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy was 0.93, while Bartlett's test of sphericity was deemed significant (x^2 = 1192.148, p < 0.001), demonstrating that the data was fitting to perform an EFA.

All the items had communalities above 0.5. The strong item communalities implied that the items explain an adequate degree of variance of the customer integration construct. The EFA revealed a one-factor solution by generating a factor with an eigenvalue above 1. 61.007% of the total variance was explained by this single-factor solution.

The scree plot also displays a well-defined break subsequent to the first factor as displayed in Figure 5.4. A factor matrix indicated that all the items loaded had excellent values above 0.7 apart from one item that was still good at 0.682. The results confirmed the uni-dimensionality of the chosen measurement items of customer integration.

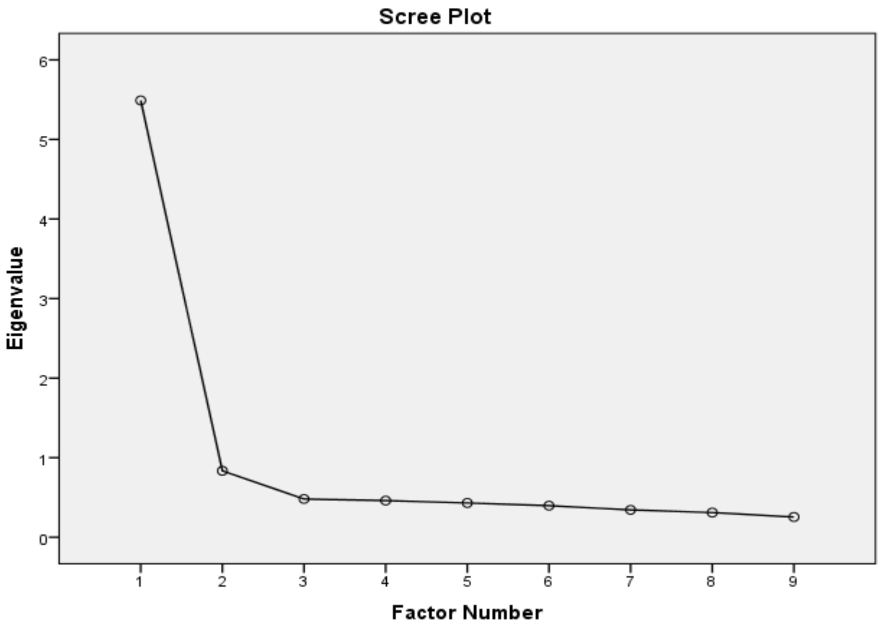


Figure 5.7 Scree plot for eigenvalues on customer integration

The EFA structure was then validated via CFA with the sample of data (n = 227). Initial analysis showed an inferior model fit at x^2 (27)=89.054, *p*=0.000 and Bollen-Stine *p*=0.005. The model fit indices were x^2/df=3.298, SRMR=0.0459, RMSEA=0.101, NFI=0.927, GFI=0.913, AGFI=0.854, CFI=0.947 and TLI=0.930. Even though CFI, NFI, GFI, TLI and SRMR values were acceptable, the rest of the indices were lower than the threshold values including the p-value.

Abiding by the same procedure used earlier to find a model fit, by analysing modification indices, standardised residual covariance matrix, squared multiple correlations and standardised loading values to identify susceptible items, items Q8_9 and Q8_3 were dropped respectively from the CFA model to achieve a better fitting model.

The resultant model demonstrated a good fitting with x^2 (14) =15.507, *p*=0.527 and Bollen-Stine *p*=0.438, x^2/df=1.108, SRMR=0.0199, RMSEA=0.022, NFI=0.983, GFI=0.981, AGFI=0.963, CFI=0.998 and TLI=0.997. The factor loadings were found significant ($p < 0.001$) and were between 0.737 to 0.800.

The measurement model for customer integration is displayed in Figure 5.8. The EFA and CFA results for the measurement model for customer integration are presented in Table 5.8.

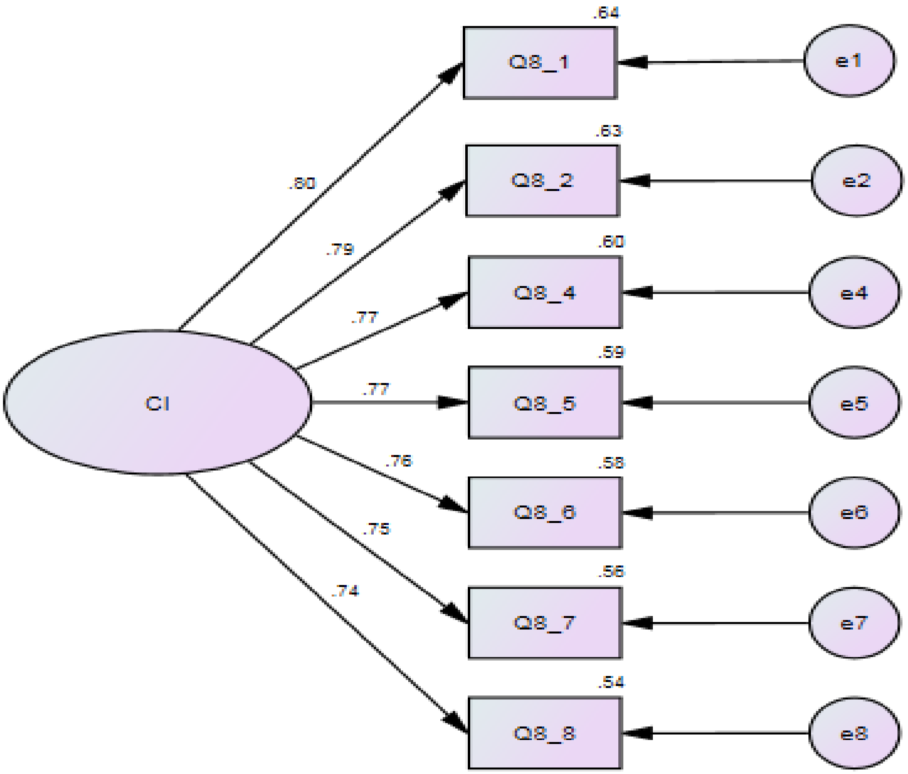


Figure 5.8 Measurement model for customer integration

Table 5.8 Factor analysis of customer integration items

Item		**EFA**		**CFA**		
Item no	**Item Description**	**Loading**	**Variance explained**	**SFL**	**t-value**	**SMC**
Q8_1	Improve the strength of linkages with our customers.	0.788	61.01 %	0.800	A	0.640
Q8_2	Improve regular contacts with our customers.	0.828		0.794	13.078*	0.630
Q8_3	Improve communication with our customers on products and promotions.	0.708		Item dropped in CFA		
Q8_4	Make and adopt demand forecasts with a real-time understanding of market trends.	0.791		0.773	12.63*	0.597
Q8_5	Improve the customer shopping experience/time/ordering/customising processes.	0.761		0.767	12.511*	0.588
Q8_6	Accurately plan and adopt the checkout/dispatch/delivery processes through a better understanding of market trends.	0.729		0.760	12.38*	0.578

Q8_7	Improve the check-out/dispatch/delivery process of goods.	0.707		0.747	12.104*	0.558
Q8_8	Improve and simplify the payment receivable process from our customers.	0.741		0.737	11.906*	0.544
Q8_9	Improve our customer feedback process.	0.682		Item dropped in CFA		
		igenvalue = 5.491; KMO =0.930; Bartlett's test of sphericity: x^2= 1192.148, p<0.001		*x^2 (14) = 15.507, p=0.527* x^2/df=1.108, SRMR=.0199 RMSEA=0.022, NFI=0.983 GFI=0.981, AGFI=0.963 CFI=0.998, TLI=0.997		

Note: Adjusted goodness-of-fit (AGFI); CFA=Confirmatory Factor Analysis; CFI=Comparative Fit Index; EFA=Exploratory Factor Analysis; GFI=Goodness-of-Fit Index; KMO=Kaiser-Meyer-Olkin Measure of Sampling Adequacy; Normed fit index (NFI); RMSEA=Root Mean Square Error of Approximation; SMC=Squared Multiple Correlation; SFL=Standardised Factor Loadings; SRMR=Standardised Root Mean Square Residual; TLI=Tucker-Lewis Index;
*$p<0.001$

5.5.5 Measurement model for supply chain performance

Using the calibration sample (n = 227), an EFA was performed with having principal axis factoring as the extraction method and direct oblimin as the rotation method. Small coefficients at the absolute value below 0.3 were suppressed.

There were 36 correlations altogether, out of which there were no partial correlations above the cut-off point of 0.7 and had 2 correlations less than 0.3. Lesser correlations were Q9_1 against Q9_5 and Q9_7. They were both closer to 0.3 (.282 and .277 respectively). While the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy resulted in 0. 0.924, the Bartlett's test of sphericity was found significant (x^2 = 785.473, p < 0.001). The results revealed that the data set was appropriate for conducting an EFA.

All items had communalities above 0.3, apart from the item Q9_1, indicating 0.260. This low communality value implied that the item accounted for not enough variance of the supply chain construct and was therefore deleted. The item removed is the same item that exhibited lower correlation against a couple of other items.

Subsequent to the deletion of the item Q9_1, the remaining items were once more subjected to an EFA. This time all the correlations appeared lower than the cut-off point of 0.7 and had no correlations below 0.3. The Kaiser-Meyer-Olkin (KMO) test of sampling adequacy was at 0.924. Also, Bartlett's test of sphericity was significant (x^2 = 719.726, p < 0.001). Therefore, the suitability of the study dataset for an EFA was confirmed.

All the items communalities were greater than 0.3, with a minimum of 0.378, indicating that all the tested items are capable of explaining an adequate amount of variance of the construct. A single-factor solution with an eigenvalue above 1 was generated. The total variance explained by this resulting single-factor solution was 54.515%. The scree plot also displays a well-defined break subsequent to the first factor as displayed in Figure 5.9. Factor matrix indicated that all the items loaded had values above 0.64. The results confirmed the uni-dimensionality of the opted measurement items of the supply chain performance.

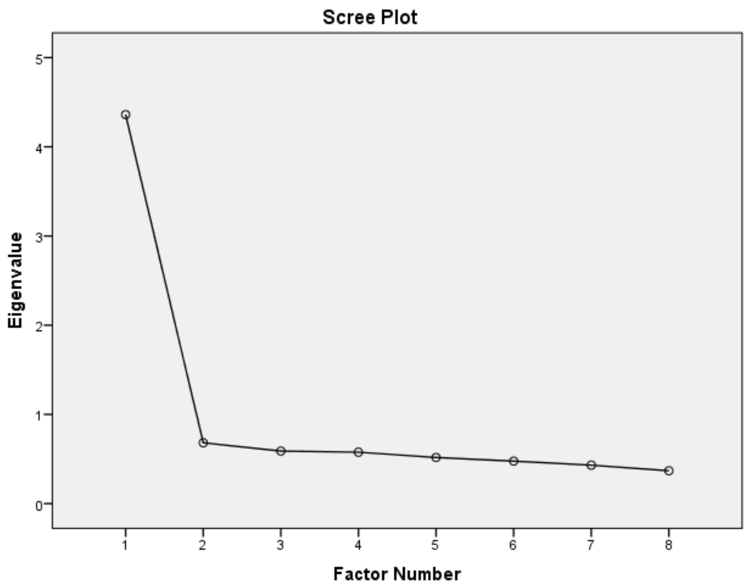


Figure 5.9 Scree plot for eigenvalues on supply chain performance

The EFA structure was later validated via CFA, by using the sample of data (n = 227). The results straight away revealed a good fitting model with x^2 (20)=17.292, *p*=0.634 and Bollen-Stine *p*=0.667, x^2/df=0.865, SRMR=0.0241, RMSEA=0.000, NFI=0.976, GFI=0.981, AGFI=0.966, CFI=1.00 and TLI=1.005. The resultant factor loadings were found significant ($p < 0.001$) and were between 0.637 to 0.758.

The measurement model for supply chain performance is displayed in Figure 5.10. The EFA and CFA results for the measurement model for supply chain performance are shown in Table 5.9.

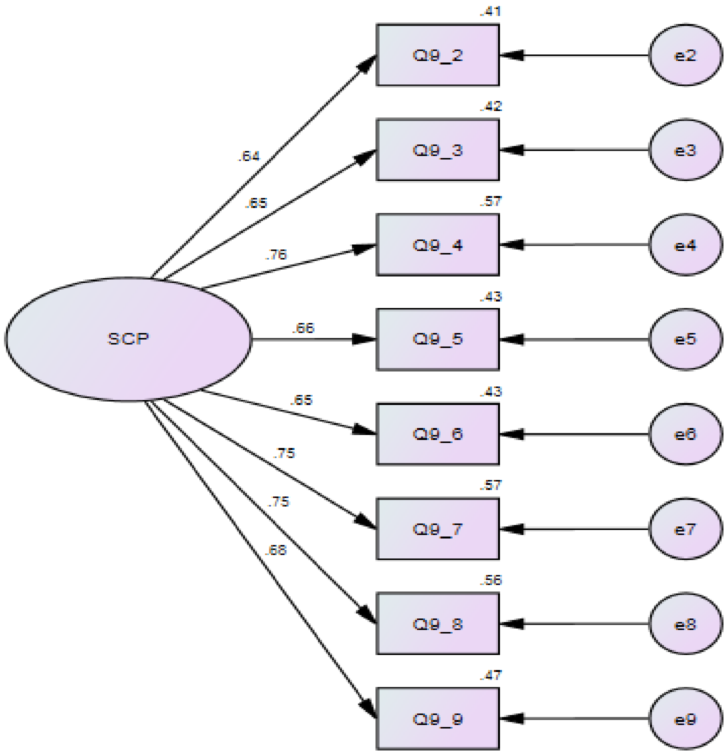


Figure 5.10 Measurement model for supply chain performance

Table 5.9 Factor analysis of supply chain performance items

Item		EFA		CFA		
Item no	**Item Description**	**Loading**	**Variance explained**	**SFL**	**t-value**	**SMC**
Q9_1	Improve product quality.	Dropped in EFA	0.545	Dropped in EFA		
Q9_2	Improve supply chain delivery reliability.	0.641		0.637	A	0.406
Q9_3	Improve fill rates.	0.656		0.651	8.307*	0.424
Q9_4	Improve perfect order fulfilment (deliveries with no errors).	0.759		0.758	9.351*	0.574
Q9_5	Improve supply chain flexibility (react to product changes, volume, mix).	0.652		0.656	8.36*	0.430
Q9_6	Reduce the cash-to-cash cycle time.	0.653		0.652	8.319*	0.425
Q9_7	Reduce the total supply chain management cost.	0.753		0.753	9.304*	0.566
Q9_8	Reduce the cost of goods sold.	0.742		0.748	9.257*	0.559

Q9_9	Improve value-added productivity (sales per employee).	0.681		0.683	8.632*	0.466
		Eigenvalue = 4.361; KMO =0.924; Bartlett's test of sphericity: x^2= 719.727, p<0.001		*x^2 (20) = 17.292, p = 0.634* x^2/df=0.865, SRMR=0.0241 RMSEA=0.000, NFI=0.976 GFI=0.981, AGFI=0.966 CFI=1.00, TLI=1.005		

Note: Adjusted goodness-of-fit (AGFI); CFA=Confirmatory Factor Analysis; CFI=Comparative Fit Index; EFA=Exploratory Factor Analysis; GFI=Goodness-of-Fit Index; KMO=Kaiser-Meyer-Olkin Measure of Sampling Adequacy; Normed fit index (NFI); RMSEA=Root Mean Square Error of Approximation; SMC=Squared Multiple Correlation; SFL=Standardised Factor Loadings; SRMR=Standardised Root Mean Square Residual; TLI=Tucker-Lewis Index;
*p<0.001

5.5.6 Measurement model for firm performance

Using the calibration sample (n = 227), an EFA was performed with having principal axis factoring as the extraction method and direct oblimin as the rotation method. Small coefficients at the absolute value below 0.3 were suppressed as usual.

In this case, there were, in total, 55 correlations. The results indicated that all correlations were higher than 0.3, while all partial correlations were below 0.7. In addition, the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy value was 0.945, together with significant Bartlett's test of sphericity (x^2 = 1248.043, p < 0.001). All statistics revealed that the data set was appropriate for conducting an EFA.

All the items had communalities above 0.3, with 0.334 being the lowest. EFA revealed a single-factor solution with an eigenvalue above 1. While, the total variance explained by this attained single-factor solution was 54.768%, the scree plot also displayed a well-defined break subsequent to the first factor as displayed in Figure 5.11. Factor matrix indicated that all the items loaded had values above 0.576. The results confirmed the uni-dimensionality of the opted measurement items of firm performance.

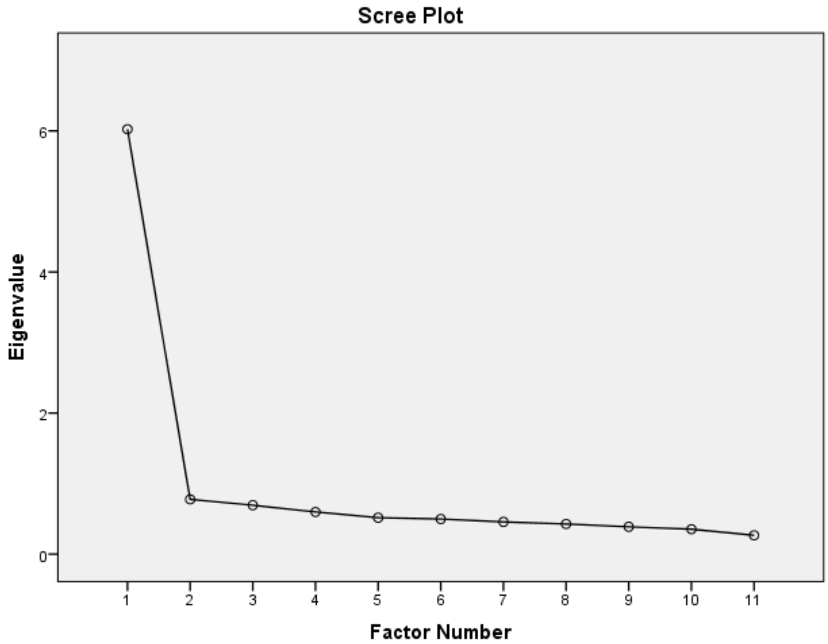


Figure 5.11 Scree plot for eigenvalues on firm performance

Same as for the earlier constructs, the EFA structure was subsequently validated via CFA. The results indicated an inferior model fit with $x^2(44)=67.698$, $p=0.012$ and Bollen-Stine $p=0.04$. The fit indices for the model were $x^2/df=1.539$, SRMR=0.0334, RMSEA=0.049, NFI=0.947, GFI=0.948, AGFI=0.922, CFI=0.981 and TLI=0.976. Even though all fit indices reached the threshold levels, the p-value was below the tolerance value ($p>0.05$) for a model with less than 12 items.

The analysis of modification indices, standardised residual covariance matrix, squared multiple correlations and standardised loading values identified Q10_4 as a susceptible item, therefore dropped from the CFA model with the purpose of achieving a better fitting model. The consequential model demonstrated a good fitting model with x^2 (35) = 34.947, $p=0.471$ and Bollen-Stine p =0.512, $x^2/df=0.998$, SRMR=0.0253, RMSEA=0.000, NFI=0.969, GFI=0.970, AGFI=0.953, CFI=1.000 and TLI=1.000. The factor loadings were found significant ($p < 0.001$) and were between 0.566 to 0.811.

The measurement model of firm performance is displayed in Figure 5.12. The EFA and CFA results for the measurement model for firm performance are presented in Table 5.10.

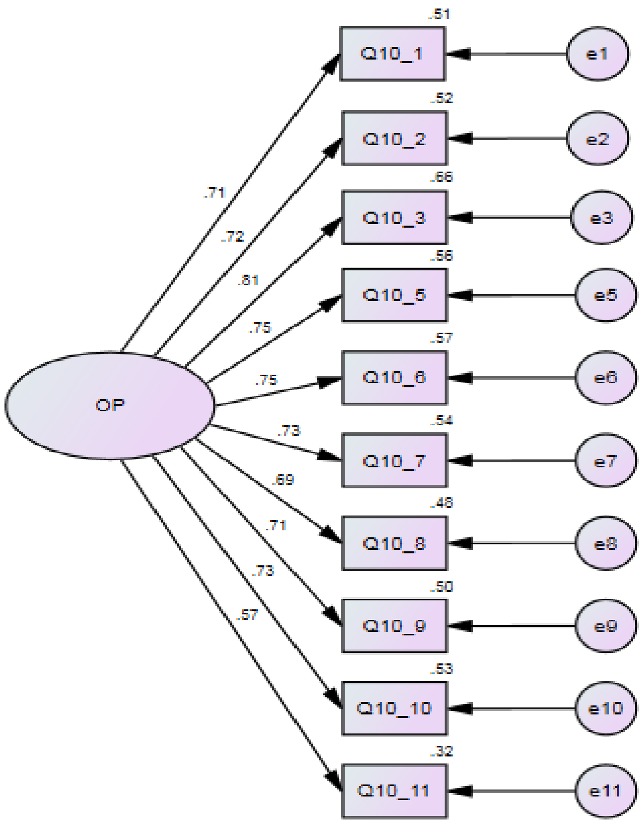


Figure 5.12 Measurement model for firm performance

Table 5.10 Factor analysis of firm performance items

Item		**EFA**		**CFA**		
Item no	**Item Description**	**Loading**	**Variance explained**	**SFL**	**t-value**	**SMC**
Q10_1	Improve the product delivery cycle time.	0.715	0.548	0.712	a	0.506
Q10_2	Improve productivity (e.g. assets, operating costs, labour costs).	0.714		0.719	10.34*	0.518
Q10_3	Improve sales of existing products.	0.828		0.811	11.641*	0.659
Q10_4	Find new revenue streams (e.g. new products, new markets).	0.606		Item dropped in CFA		
Q10_5	Building strong and continuous bonds with customers.	0.741		0.750	10.771*	0.562
Q10_6	Gaining precise knowledge of customer buying patterns.	0.741		0.752	10.804*	0.566
Q10_7	Improve customer satisfaction.	0.735		0.735	10.56*	0.540
Q10_8	Improve employee satisfaction.	0.688		0.690	9.916*	0.476

Q10_9	Improve employee health and safety.	0.701		0.709	10.191*	0.503
Q10_10	Reduce energy use.	0.730		0.725	10.424*	0.526
Q10_11	Improve return/re-use/recycle.	0.576		0.566	8.151*	0.321
		Eigenvalue= 6.024; KMO =0.945; Bartlett's test of sphericity: x^2= 1248.043, p<0.001		*x^2 (35) = 34.947, p = 0.471* x^2/df=0.998, SRMR=0.0253 RMSEA=0.000, NFI=0.969 GFI=0.970, AGFI=0.953 CFI=1.000, TLI=1.000		

Note: Adjusted goodness-of-fit (AGFI); CFA=Confirmatory Factor Analysis; CFI=Comparative Fit Index; EFA=Exploratory Factor Analysis; GFI=Goodness-of-Fit Index; KMO=Kaiser-Meyer-Olkin Measure of Sampling Adequacy; Normed fit index (NFI); RMSEA=Root Mean Square Error of Approximation; SMC=Squared Multiple Correlation; SFL=Standardised Factor Loadings; SRMR=Standardised Root Mean Square Residual; TLI=Tucker-Lewis Index;
*p<0.001

5.5.7 The full measurement model

Subsequent to independently establishing the measurement models for each construct, a combined measurement model of all the constructs in one CFA model was tested with the sample (n = 227) (Tanaka 1987). A good fitting model at x^2 (1112) = 1470.579, p = 0.000 and Bollen-Stine p = 0.109 was revealed. The model fit indices were x^2/df =1.322, SRMR=0.0478, RMSEA=0.038, NFI=0.814, GFI=0.792, AGFI=0.771, CFI=0.947 and TLI=0.944.

Given that the number of observed variables is over 30 and n < 250, significant p-value and noncompliance of GFI, AGFI and NFI indices were anticipated and tolerable, therefore not considered (Hair et al. 2014; Hu & Bentler 1998; Hu & Bentler 1999). As argued earlier in the section, GFI, AGFI and NFI were overlooked due to their poor performance in small samples and were rejected in favour of more relevant contemporary fit indices (Fan et al. 1999; Hair et al. 2014; Iacobucci 2010; Maiti & Mukherjee 1991). However, the chi-square value is found to be a poor model fit of data because of the associated p-value less than 0.05. (Hair et al. 2014, p. 584). However, it is stated that when the model contains over 30 measurement items and the number of observed variables is fewer than 250, a p-value of less than 0.05 (p <.05) is acceptable. It was decided that the x^2 test not be the most suited model fit measure for this sample as it is small and multivariate non-normal (Hu et al. 1992; Nevitt & Hancock 2001; Schumacker & Lomax 2004). Therefore, Bollen-Stine bootstrap x^2 test was performed and Bollen-Stine p value was taken into consideration (i.e. more than p>0.05) (Bollen & Stine 1992). Many previous studies have not reported p-value but appear to apply bootstrapping procedures in testing smaller samples to fit the model (Qrunfleh & Tarafdar 2014; Rai et al. 2006; Ralston et al. 2015). Therefore, the model fit is argued to be acceptable. The fit indices in this study that was taken into account suggested a satisfactory model fit.

However, the resulting squared multiple correlations of a couple of items were lower than the cut-off levels, and standardised factor loadings were below 0.6. That indicated that the removal of items Q4_8 and Q10_11 could improve the model. The consequential model improved the model fit at x^2 (1019) = 1316.182, p = 0.000 and Bollen-Stine p=0.144, x^2/df=1.292, SRMR =0.0463, RMSEA=0.036, NFI=0.827, GFI=0.802, AGFI=0.781, CFI=0.954 and TLI=0.952. The evidence that all standardised factor loadings are statistically significant and over 0.6 (most higher than the ideal value of 0.7) also supported the appropriateness of the items (Anderson & Gerbing 1988; Hair et al. 2014).

A brief convergent validity test (there will be a comprehensive validity test later in section 5.6.2) was conducted by examining average variance extracted (AVE) for each construct (Hair et al. 2014). The supply chain performance construct was below 0.5, the minimum adequate convergence level (Bagozzi & Yi 1988; Fornell & Larcker 1981; Hair et al. 2014). The supply chain performance construct indicating an AVE value less than 0.5 meaning that, on average, there is more error in the items than variance explained by the latent factor structure (Hair et al. 2014).

To improve AVE value of the supply chain performance construct, the item (Q9_3) that had the least squared factor loading (0.409) was deleted. Even though the AVE value improved to 0.489, the value did not comply with the minimum adequate convergence level. Therefore, item Q9_2, which displayed the least squared factor loading (0.401) in the new model was removed. The removal of two items resulted in an AVE value for the supply chain performance construct of 0.505 in compliance with the minimum requirement to confirm the convergent validity of all constructs in the model.

Inevitably, the model fit indices were improved with the modifications. The concluding values for model fit indices were x^2 (930)=1366.876, p=0.000, Bollen-Stine p=0.194, x^2/df=1.255, SRMR=0.0451, RMSEA=0.034, NFI=0.839, GFI=0.812, AGFI=0.791, CFI=0.962 and TLI=0.960.

Considering these facts, this combined model illustrated in Figure 5.13 formed the full measurement model. The results of the full measurement model are on Table 5.11.

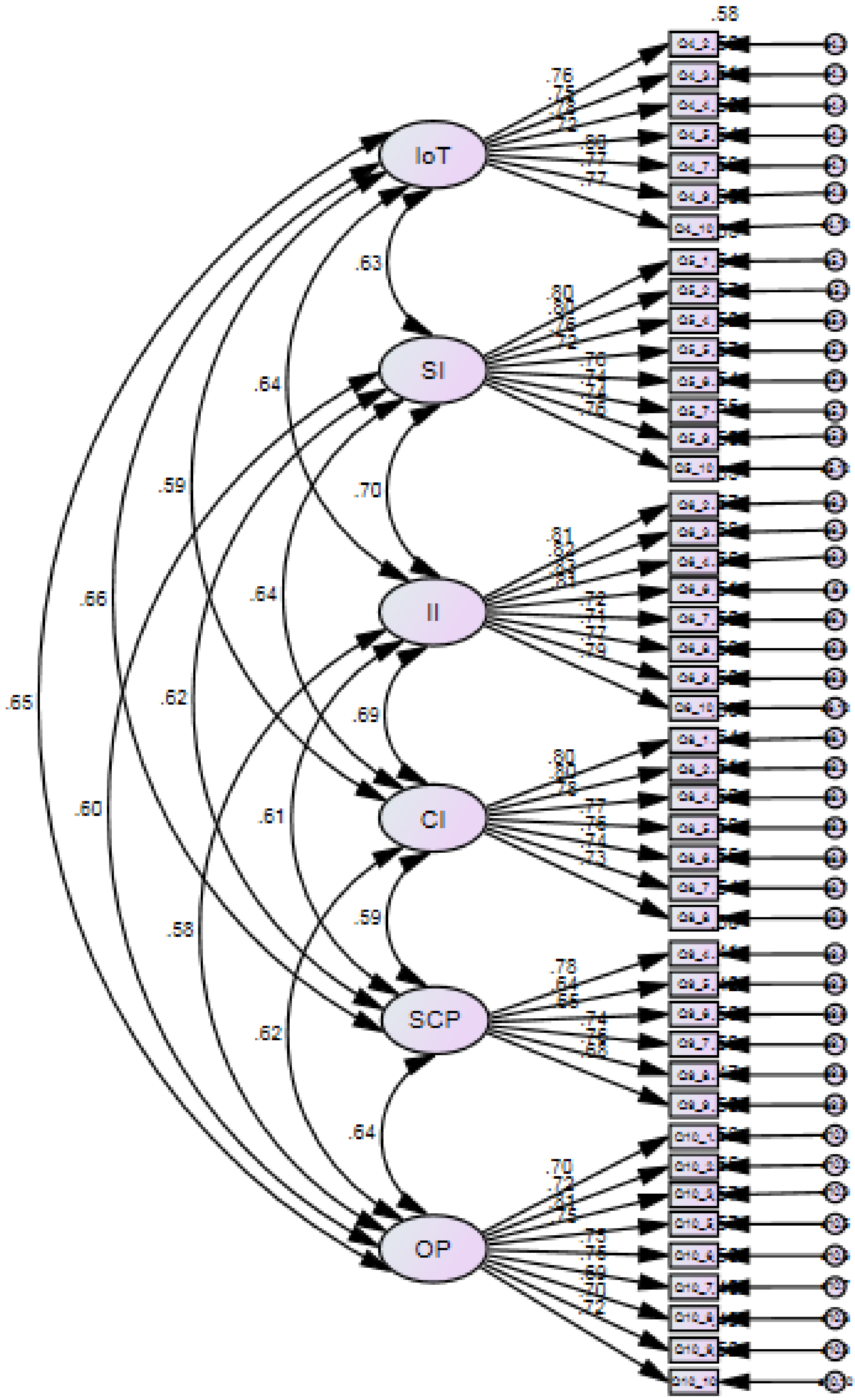


Figure 5.13 Full measurement model

Table 5.11 Results of the full measurement model

Item no	Item Description	SFL	t-value	SMC
IoT capability				
Q4_2	To provide unit level (product group/pallet) identification.	0.759	12.109*	0.576
Q4_3	To monitor, track and trace supply chain entities and people through auto-captured data.	0.749	11.919*	0.561
Q4_4	To measure supply chain activities, processes and its environmental conditions.	0.781	a	0.61
Q4_5	To help control supply chain processes remotely.	0.718	11.323*	0.515
Q4_7	To provide real-time information to optimise supply chain activities	0.798	12.88*	0.637
Q4_9	To provide large volumes and variety of data to apply data analytics for tactical and strategic decision making.	0.767	12.26*	0.588
Q4_10	To strengthen inter and intra organisational information sharing within the supply chain.	0.774	12.398*	0.598
Supplier integration				
Q5_1	Improve information exchange with our suppliers.	0.803	13.469*	0.645
Q5_2	Establish a quick ordering of inventory from our suppliers.	0.798	a	0.637
Q5_4	Stabilize procurement with our suppliers.	0.758	12.489*	0.575
Q5_5	Share real-time demand forecasts with our suppliers.	0.721	11.71*	0.52
Q5_6	Improve strategic partnerships with our suppliers.	0.758	12.478*	0.574
Q5_7	Help our suppliers improve their processes to better meet our needs.	0.738	12.057*	0.544
Q5_9	Improve the transport/logistics processes for logistics partners to deliver orders just in time.	0.742	12.149*	0.551
Q5_10	Improve our receiving processes for delivered goods.	0.762	12.581*	0.581
Internal integration				
Q6_2	Improve real-time communication and linkage among all internal functions.	0.806	14.38*	0.65
Q6_3	Accurately plan and adopt internal processes in collaboration with cross functional teams.	0.819	14.718*	0.671
Q6_4	Make and adopt demand forecasts in collaboration with cross functional teams.	0.827	a	0.685
Q6_6	Improve real-time searching of the inventory levels.	0.808	14.433*	0.654
Q6_7	Improve real-time searching of logistics-related operating data.	0.717	12.17*	0.514
Q6_8	Employ cross functional teams in process improvement.	0.706	11.918*	0.499
Q6_9	Improve replenishment of shop floor shelves.	0.766	13.343*	0.587
Q6_10	Reduce stock outs in the shop floor shelves.	0.789	13.912*	0.622
Customer integration				
Q8_1	Improve the strength of linkages with our customers.	0.796	12.812*	0.634
Q8_2	Improve regular contacts with our customers.	0.798	12.856*	0.638
Q8_4	Make and adopt demand forecasts with a real-time understanding of market trends.	0.778	a	0.606
Q8_5	Improve the customer shopping experience/time/ordering/customising processes.	0.771	12.325*	0.595

Q8_6	Accurately plan and adopt the checkout/dispatch/delivery processes through a better understanding of market trends.	0.759	12.082*	0.576
Q8_7	Improve the check-out/dispatch/delivery process of goods.	0.739	11.693*	0.545
Q8_8	Improve and simplify the payment receivable process from our customers.	0.734	11.606*	0.539
Supply chain performance				
Q9_4	Improve perfect order fulfilment (deliveries with no errors).	0.776	a	0.603
Q9_5	Improve supply chain flexibility (react to product changes, volume, mix).	0.643	9.601*	0.413
Q9_6	Reduce the cash-to-cash cycle time.	0.646	9.655*	0.417
Q9_7	Reduce the total supply chain management cost.	0.74	11.24*	0.547
Q9_8	Reduce the cost of goods sold.	0.764	11.665*	0.584
Q9_9	Improve value-added productivity (sales per employee).	0.684	10.291*	0.468
Firm performance				
Q10_1	Improve the product delivery cycle time.	0.705	10.744*	0.497
Q10_2	Improve productivity (e.g. assets, operating costs, labour costs).	0.719	10.981*	0.516
Q10_3	Improve sales of existing products.	0.808	12.526*	0.652
Q10_5	Build strong and continuous bonds with customers.	0.754	a	0.568
Q10_6	Gain precise knowledge of customer buying patterns.	0.753	11.574*	0.567
Q10_7	Improve customer satisfaction.	0.75	11.52*	0.563
Q10_8	Improve employee satisfaction.	0.693	10.544*	0.48
Q10_9	Improve employee health and safety.	0.703	10.723*	0.495
Q10_10	Reduce energy use.	0.719	10.984*	0.517

x^2 (930) = 1366.876, p = 0.000, Bollen-Stine p = 0.194, x^2/df = 1.255, SRMR = 0.0451, RMSEA=0.034, NFI=0.839, GFI=0.812, AGFI=0.791, CFI=0.962 and TLI=0.960

Note: Adjusted goodness-of-fit (AGFI); CFA=Confirmatory Factor Analysis; CFI=Comparative Fit Index; EFA=Exploratory Factor Analysis; GFI=Goodness-of-Fit Index; KMO=Kaiser-Meyer-Olkin Measure of Sampling Adequacy; Normed fit index (NFI); RMSEA=Root Mean Square Error of Approximation; SMC=Squared Multiple Correlation; SFL=Standardised Factor Loadings; SRMR=Standardised Root Mean Square Residual; TLI=Tucker-Lewis Index;
*p<0.001

5.6 Assessment of the measurement model

One of the key objectives of CFA is to evaluate the construct validity of a proposed measurement theory (Hair et al. 2014). Therefore, after identifying the measurement model and its items, the extent to which the research is accurate was then established (Hair et al. 2014). The model and its items were tested to validate their ability to represent their respective study constructs and also their capacity to distinguish between the measurement items of different constructs, thus the accuracy of measurement. Accordingly, the items were evaluated by applying reliability and validity tests. It is important to confirm the reliability and validity of the measurement model ahead of testing the structural model, as it affects the structural analysis (Blunch 2012; Hair et al. 2014). Thereafter, statistical procedures were used to examine common method bias. Also, the possible presence of measurement variance that could take place, due to diverse groups of respondents participating in the survey, was also examined.

5.6.1 Reliability assessment

The constructs and its items in the final model were reviewed for its reliability by testing their Cronbach's alpha and composite reliability. The Cronbach's alpha (Cronbach 1951) value for this study was calculated using SPSS 23. The analysis indicated values higher than 0.9, corroborating an excellent level of reliability for all constructs but one. Supply chain performance construct also indicated a good degree of reliability at 0.856 (Bernstein & Nunnally 1994; DeVellis 2016; Hair et al. 2014; Kline 2013; Nunnally 1978). The composite reliability values (construct reliability CR), were calculated by applying AMOS 23 results. All but one of the CR values were higher than 0.8 which indicated excellent levels of construct reliability, except for the supply chain performance construct which yet again indicated a good degree of reliability at 0.745 (Hair et al. 2014). The outcomes inferred the consistency of the items that was representing the constructs and their reliability to measure the constructs. Also, the correlation between constructs being lower than 0.8 indicates that there are no multicollinearity issues between constructs (Hair et al. 2014). The outcomes of the tests of reliability are presented in Table 5.12.

Table 5.12 Reliability tests table

Construct	No. of items	IoT	SI	II	CI	SCP	OP	Mean	SD	Cr. Alpha	CR
IoT capability	7	1						4.823	1.273	0.907	0.859
Supplier integration	8	0.632	1					4.723	1.324	0.915	0.862
Internal integration	8	0.641	0.697	1				4.500	1.365	0.925	0.870
Customer integration	7	0.591	0.644	0.689	1			4.719	1.325	0.909	0.852
Supply chain performance	8	0.657	0.632	0.627	0.595	1		4.648	1.447	0.856	0.745
Firm performance	9	0.647	0.598	0.584	0.616	0.620	1	4.444	1.407	0.912	0.842

Note: CR= Composite reliability; Cr. Alpha=Cronbach's alpha; SD=Standard deviation

*All correlation coefficients are significant at $p < .001$.

The extent of the factor loading is a vital consideration. Therefore, the item reliabilities were further confirmed by examining factor loadings. The standardised factor loadings should be at least over 0.5 and ideally over 0.7 (Hair et al. 2014). The measurement items that exhibit factor loadings above 0.7 retain a higher shared variance with the construct than the error variance (Hair et al. 2014; Jöreskog & Sörbom 1982). Out of 45 standardised factor loadings, 41 were higher than 0.7, and the lowest was 0.643. The reliability values were statistically significant with most above the ideal scale, and the rest are closer to the ideal parameter, which further confirmed the reliability of the items (Anderson & Gerbing 1988; Hair et al. 2014).

5.6.2 Construct validity assessment

The average variance extracted (AVE) for each construct was tested to confirm convergent validity. AVE represents the degree of item variation explained by the construct (Hair et al. 2014). It is a summary indicator for convergence, computed by means of dividing the sum of squared factor loadings (Squared Multiple Correlations) by total number of items (Fornell & Larcker 1981; Hair et al. 2014).

The AVE of each construct were 0.584 for IoT capability, 0.578 for supplier integration, 0.61 for internal integration, 0.59 for customer integration, 0.505 for supply chain performance and 0.5393 for firm performance. The values over 0.5 suggested that all of the item variations coulde be explained by the latent factor structures of the study (Bagozzi & Yi 1988; Fornell & Larcker 1981; Hair et al. 2014). The AVE value for the supply chain performance construct was the least but was still above 0.5, complying with the minimum adequate convergence point (Fornell & Larcker 1981; Hair et al. 2014). Thus, the convergent validity of all constructs was confirmed.

Thereafter, a nested model comparison using CFA was conducted to verify discriminant validity (Anderson & Gerbing 1988; Bagozzi & Yi 1988; Hair et al. 2014). A sequence of CFA models were compared to each (one pair at a time) by restricting correlations between each pair of study constructs to 1. If the x^2 difference is found to be significant between the two models, discriminant validity is supported (Bagozzi & Yi 1988; Hair et al. 2014; Huo 2012). The results of the nested CFA model comparisons are displayed in Table 5.13. All the models reveal of significant x^2 differences, confirming the discriminant validity of the items.

Table 5.13 Nested model comparisons for discriminant validity

Correlation constrained to one	Δ x^2	p
IoT capability <--> Supplier integration	13.386	0.0003
IoT capability <--> Internal integration	9.1	0.0026
IoT capability <--> Customer integration	13.599	0.0002
IoT capability <--> Supply chain performance	6.97	0.0083
IoT capability <--> Firm performance	13.647	0.0002
Supplier integration <--> Internal integration	6.697	0.0097
Supplier integration <--> Customer integration	8.226	0.0041
Supplier integration <--> Supply chain performance	*7.222*	0.0072
Supplier integration <--> Firm performance	*14.367*	0.0002
Internal integration <--> Customer integration	7.058	0.0079
Internal integration <--> Supply chain performance	9.911	0.0016
Internal integration <--> Firm performance	11.683	0.0006
Customer integration <--> Supply chain performance	7.564	0.0060
Customer integration <--> Firm performance	11.484	0.0007
Supply chain performance <--> Firm performance	9.897	0.0017

Δ x^2 = x^2 difference with the unconstrained model, p = Significance of the x^2 difference, $^*p < 0.01$

In practice, however, the nested model comparison does not provide strong evidence of discriminant validity, because sometimes correlations as high as 0.9 can still produce a significant difference in fit (Hair et al. 2014). Therefore, to further confirm the results, the discriminant validity of constructs was tested via comparing the AVE value of each study construct against squared correlations of the remaining constructs of the model. The AVE should be greater than squared correlation estimates (Fornell & Larcker 1981; Hair et al. 2014). If the AVE for a construct go above the squared correlations of remaining constructs, it means that the latent construct explains more variances in its items than the variance that construct shares with other constructs (Fornell & Larcker 1981; Hair et al. 2014). The AVE values and the squared correlations are displayed in Table 5.14.

Table 5.14 Testing discriminant validity

Construct	IoT	SI	II	CI	SCP	OP
IoT capability	**0.584**					
Supplier integration	0.399	**0.578**				
Internal integration	0.411	0.486	**0.610**			
Customer integration	0.349	0.415	0.475	**0.590**		
Supply chain performance	0.440	0.381	0.377	0.350	**0.505**	
Firm performance	0.419	0.358	0.341	0.379	0.404	**0.539**

*Note: The diagonal values are AVE

*Note: squared correlations are displayed below the diagonal

Table 5.14 indicates that all the constructs had AVE values above its squared correlations. Therefore, the discriminant validity of the constructs was confirmed. Passing this rigorous test can provide real evidence of discriminant validity (Hair et al. 2014).

5.6.3 Common method bias

Rigorous actions that was undertaken to minimise the method bias was described in Section 4.3.1.4 in the Methodology section. However, in an attempt to exclude any doubt, common method bias was yet, statistically examined with Harman's single-factor test and Marker variable test.

The Harman (1967) single-factor test was performed applying both EFA and CFA (Flynn et al. 2010; Podsakoff et al. 2003). Firstly, the EFA based model resulted in above a single factor (7 in total) with eigenvalues over 1. Those resultant 7 factors represented 65.923% of the total variance, alongside the first factor representing 40.485% of the total variance, which is not the majority of the variance. When the number of factors was fixed to one, EFA derived a single-factor explaining 39.171% of total variance.

As a secondary analysis, Harmon's single factor test based on CFA was conducted. The CFA model having all manifest variables acting as indicators of a single factor, revealed a way inferior model fit with x^2 (945) = 2904.316, p = 0.000, Boolan-Stine p= 0.005, x^2/df = 3.073, GFI = 0.529, TLI = 0.672, CFI=0.623, RMSEA = 0.096 and SRMR = 0.0846. It was significantly worse than the indicators of the measurement model. This way inferior model fit indicated the absence of common method bias.

However, since Harman's single-factor test has been criticised for being unreliable and often considered outdated (Malhotra et al. 2006), Lindell and Whitney (2001), marker variable technique was also employed to confirm the absence of common method bias. The Australian tourism industry questions (Q7_1 to Q7_4) were initially placed in the questionnaire as the marker variable. The marker variable was theoretically unrelated to the other dependent variables (Malhotra et al. 2006). When the marker variable construct was introduced to the full CFA measurement model, there was no significant relationship to any of the other constructs. Table 5.15 displays the correlation between study contracts and the marker variable. The results further indicated that common method bias was not an issue in this study.

Table 5.15 The correlations between study contracts and the marker variable

Study construct vs Marker variable	Correlation	p-value
IoT capability <--> Marker variable	0.131	0.084
Supplier integration <--> Marker variable	0.104	0.164
Internal integration <--> Marker variable	0.098	0.19
Customer integration <--> Marker variable	0.027	0.716
Supply chain performance <--> Marker variable	0.016	0.836
Firm performance <--> Marker variable	0.123	0.104

5.6.4 Measurement invariance

The measurement model was tested to verify if the model validity is comparable among dissimilar demographics in the sample population using the following steps (Perera 2016). The measurement model for separate individual groups were tested to verify configural invariance. The existing model was the baseline model compared to when tested for metric invariance. Second, measurement models belong to the demographic groups were simultaneously analysed. Thirdly, in order to determine the metric invariance, two models were compared as constrained and unconstrained models. While variances, covariances, error variances and factor loadings were set uniform across groups in the constrained model, in the unconstrained model, all parameters were freely estimated. What this implies is that the constrained model is nested within the unconstrained model. Despite the x^2 difference test is capable of examining nested models, its suitability for invariance decisions have reservations about (Byrne 2013; Hair et al. 2014). A better approach is to assess CFI values differences between the constrained and unconstrained models, since CFI difference is not dependent on sample size or the model complexity or neither correlates with the overall fit measures (Cheung & Rensvold 2002; Hair et al. 2014). Therefore, the x^2 difference, as well as CFI differences were assessed.

The study responses originate from various sectors based on the firm size, the geographic scope of the supply chain network and retail model. Larger organisations may have higher resources for technology integration in supply chains (Rai et al. 2006; Zhao et al. 2011). Consequently, they could be in a better position to implement IoT in supply chains. Similarly, the demographics can have an influence on IoT deployment, adaptation and performance. Thus, organisation's retail model and the geographic scope of their supply chain operations can have an impact on process and technology capabilities.

Firstly, the data set was separated by the firm size. The classification of the Australian Bureau of Statistics for organisation size was applied to this study. Responses from larger organisations with over 200 workers (n=113) were grouped against the rest which was small and medium organisations (n=114). Small sample size can result in negative error variance (Blunch 2012). Therefore the clusters of small (n=10) and medium (n=104) firms were merged for this exercise.

Model fit indices of the two baseline models based on firm size are as below. Model fit indices for large firm size group (n=113); $x^2(930)=1170.549$, $p=0.000$ and Bollen-Stine $p=0.736$, $x^2/df=1.259$, SRMR= .0703, RMSEA=.048, NFI=.665, GFI=.705, AGFI=.662, CFI=.904 and TLI=.902. For the group of small and medium (n=114); $x^2(930)=1133.280$, $p=0.000$ and Bollen-Stine $p=0.731$, $x^2/df=1.219$, SRMR=.0532, RMSEA=.044, NFI=.753, GFI=.717, AGFI=.686, CFI=.944 and TLI=.940. Same as earlier instances, GFI, AGFI and NFI were disregarded in favour of more relevant fit indices (Fan et al. 1999; Hair et al. 2014; Iacobucci 2010; Maiti & Mukherjee 1991). The model fit of both groups was acceptable indicating well-fitting models. After that, the two groups were simultaneously analysed. The model fit indices were $x^2(1860)=2303.846$, $p=0.000$ and Bollen-Stine $p=0.771$, $x^2/df=1.239$, SRMR=0.0703, RMSEA=0.033, NFI=0.715, GFI=0.712, AGFI=0.679, CFI=0.927 and TLI=0.923 demonstrating an acceptable model fit. The above analysis established the configural invariance of the measurement model between large firm size group and the small and medium size group.

The next step was to test the metric invariance comparing a constrained model against an unconstrained model. The factor loadings were set equal across groups in the constrained model, and in contrast, the factor loadings among groups were freely estimated in the unconstrained model. The values of x^2 and CFI of the constrained and the unconstrained models are presented in Table 5.16.

Table 5.16 Constrained and unconstrained models for metric invariance for respondents from large vs small and medium organisations

Model	x^2	Df	CFI
Unconstrained	2303.846	1860	0.927
Constrained model	2361.876	1905	0.925

A x^2 difference of 58.03 was indicated for a change of 45 in degrees of freedom. The resulting *p*-value of this difference is 0.092. This revelled non-significant variation in x^2 suggested that the two models are consistent. It is a reflection of having equal measurement weights between the two divisions. Minimal CFI differentiation at 0.002 in addition established the similarity of measurement items across both large firm size group and the small and medium size group. These results of measurement invariance advocated that both large and small and medium size groups can be collectively analysed.

In the same way, configural and metric invariances were also assessed for groups of firms based on retail model and the geographic scope of their supply chain operations. For the retail model, bricks and mortar (n=129) were grouped against multi-channel (n=88) and e-tail (n=10), while for the geographic scope of supply chain operations, the worldwide scope (n=127) was grouped against regional (n=68) and local scope (n=32). Due to the small sample size of both e-tail and local supply chain scope, they were combined with multichannel and regional scope respectively to avoid negative error variances (Blunch 2012). The model fit statistics aimed at testing metric invariance and configural invariance of the multigroups based on retail model and the geographic scope of their supply chain operations are displayed in Table 5.17. The results of the baseline models (also termed totally free (TF) models) is displayed separately for each group.

Table 5.17 Configural invariances

	Retail model			The geographic scope of SC		
	Brick & mortar	Multi-channel & online	Simultaneous TF	Worldwide	Local & regional	Simultaneous TF
	(n=129)	(n=98)		(n= 127)	(n=100)	
x^2	1193.298	1190.983	2384.684	1238.989	1185.74	2424.984
Df	930	930	1860	930	930	1860
x^2/df	1.283	1.281	1.282	1.332	1.275	1.304
P	0.000	0.000	0.000	0.000	0.000	0.000
Bollen-Stine p	0.473	0.776	0.716	0.735	0.791	0.682
SRMR	0.0516	0.0808	0.0516	0.0638	0.0581	0.0638
RMSEA	0.047	0.054	0.035	0.051	0.053	0.037
NFI	0.771	0.592	0.707	0.716	0.713	0.715
GFI	0.716	0.685	0.702	0.717	0.686	0.703
AGFI	0.683	0.649	0.668	0.685	0.651	0.67
CFI	0.938	0.865	0.915	0.909	0.919	0.913
TLI	0.934	0.856	0.909	0.903	0.913	0.908

Out of the group of retail models, for the multichannel & online groups x^2/df values, Bollen-Stine p and RMSEA indicated a well-fitting model, although some key indices applied in this study, such values as CFI, TLI and SRMR fell short of acceptable range. These variations could have caused by the smaller sample size (n<100). However, the measurement model that represented the bricks and mortar retail form and the simultaneous TF model revealed an acceptable model fit. The results have been able to establish the configural invariance of the measurement model for the sectors/groups based on retail models or forms. About the geographic scope of their supply chain operations, both baseline group models, and the simultaneous analysis of groups demonstrated adequate model fits to confirm configural invariance of the measurement model for geographic scope of their supply chain operations.

The outcomes of metric invariance tests for the groups centred on the retail model and the geographic scope of their supply chain operations are displayed in Table 5.18. The table represents x^2, df and CFI values for both baseline and constrained models as well as the differences in values of x^2, df and CFI in the constrained model contrasted the baseline (unconstrained) model and the p-value for change in x^2.

Table 5.18 Metric invariances

	Retail model			The geographic scope		
	x^2	df	CFI	x^2	df	CFI
Baseline model	2384.684	1860	0.915	2424.984	1860	0.913
Constrained model	2459.209	1905	0.91	2469.429	1905	0.913
Difference (CM-BM)	74.525	45	-0.005	44.445	45	0
p value for change in x^2	0.004151			0.495343		

According to Table 5.15, the two models based on firm size exhibiting significant x^2 values at $p < 0.05$ imply an absence in measurement invariance, even though CFI below -0.01 indicating a presence of invariance. In view of the fact that the x^2 difference test is problematic in small samples (Byrne 2013; Hair et al. 2014), the invariance judgment was derived based on the CFI in this instance. Given that the CFI was below -0.01, metric invariance of groups centred on retail model/form was substantiated.

When the constrained model based on the geographic scope was compared with the baseline unconstrained model, it indicated nonsignificant x^2 at $p < 0.05$ and identical CFI values. The results, therefore, suggested metric invariance across groups based on the geographic scope. The results of the conducted configural invariance and metric invariance tests verified the measurement invariance amongst few different groups that represented the sample population. This clarification of measurement invariance amongst diverse groups of sub-samples validates the measurement model.

5.7 Structural model and hypotheses testing

Subsequent to confirming the measurement theory by testing the relationship of indicator variables of theoretical constructs and verifying measurement reliability, validity, and invariance, the conceptual relationship of the structural relationship or the structural theory was tested by examining the paths in the structural model.

Firstly, the saturated model was tested and compared the fit indices of the CFA measurement model. The saturated structural models are considered inferior due to their failure in uncovering beyond the full measurement model (Hair et al. 2014). The fit statistics of the saturated theoretical model was identical to those obtained from the measurement model, confirming the correct transition from measurement model to structural model (Hair et al. 2014).

Thereafter, the recursive structural model was tested. The analysis resulted in $x^2(936)=1236.586$, $p=0.000$ and Bollen-Stine $p=0.095$, $x^2/df=1.321$, SRMR=0.0761, RMSEA=0.038, NFI=0.829, GFI=0.804, AGFI=0.783, CFI=0.952 and TLI=0.949. As the fit indices considered in this study were around acceptable limits, the structural model can be considered a good model fit. The structural theory is valid, as the model fit indices were not substantially worse than the measurement model (Anderson & Gerbing 1992). Out of measured indices p, GFI, AGFI and NFI were the only indices that did not comply with the acceptable range as expected due to the small sample size of the study (Hair et al. 2014; Hu & Bentler 1998; Hu & Bentler 1999). As argued earlier, GFI, AGFI and NFI were ignored due to the small sample size in favour of study relevant fit indices (Fan et al. 1999; Hair et al. 2014; Iacobucci 2010; Maiti & Mukherjee 1991). Multivariate non-normality of the data was another reason to deem the x^2 test unsuitable (Hu et al. 1992; Schumacker & Lomax 2004). Hence, Bollen-Stine p value was assessed.

The structural model is presented in Figure 5.14.

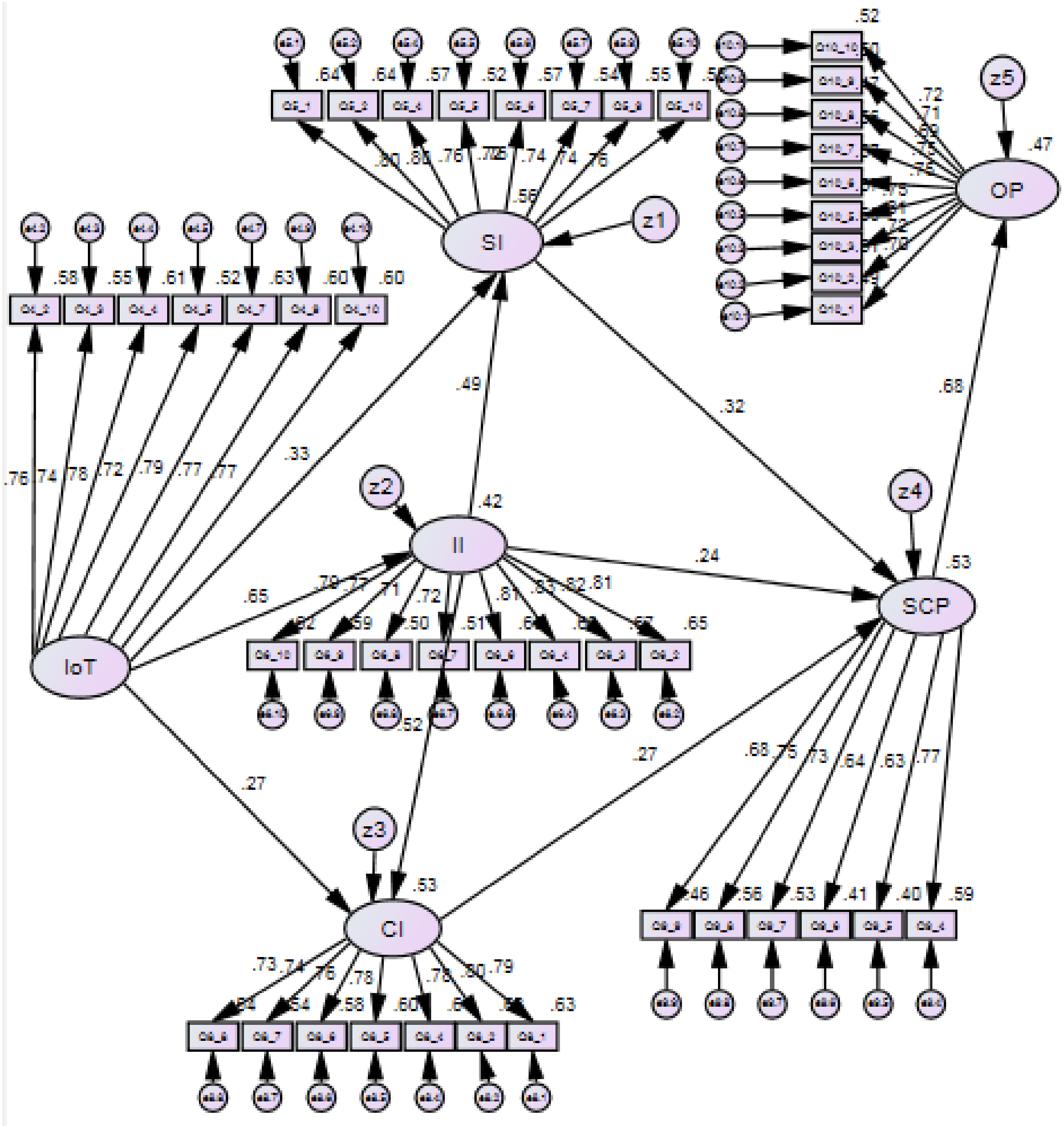


Figure 5.14 Structural path model

R^2 value or variance explained estimate of endogenous constructs points to the extent to which the model explains the variance in a construct (Byrne 2013; Hair et al. 2014). Thus, the R^2 values of the endogenous constructs also reflect the explanatory power of the model (Hair et al. 2014). In consequence, R^2 values of the structural model indicates that the model explains 56% of the variance in supplier integration, 42% variance of internal integration, 53% variance of customer integration, 53% variance in supply chain performance and 47% variance in firm performance.

The results indicated that all nine theorised structural paths are significant as displayed in Figure 5.15. The hypotheses, their respective standardised ß coefficients of the path estimates and the *p* values are summarised in Table 5.19.

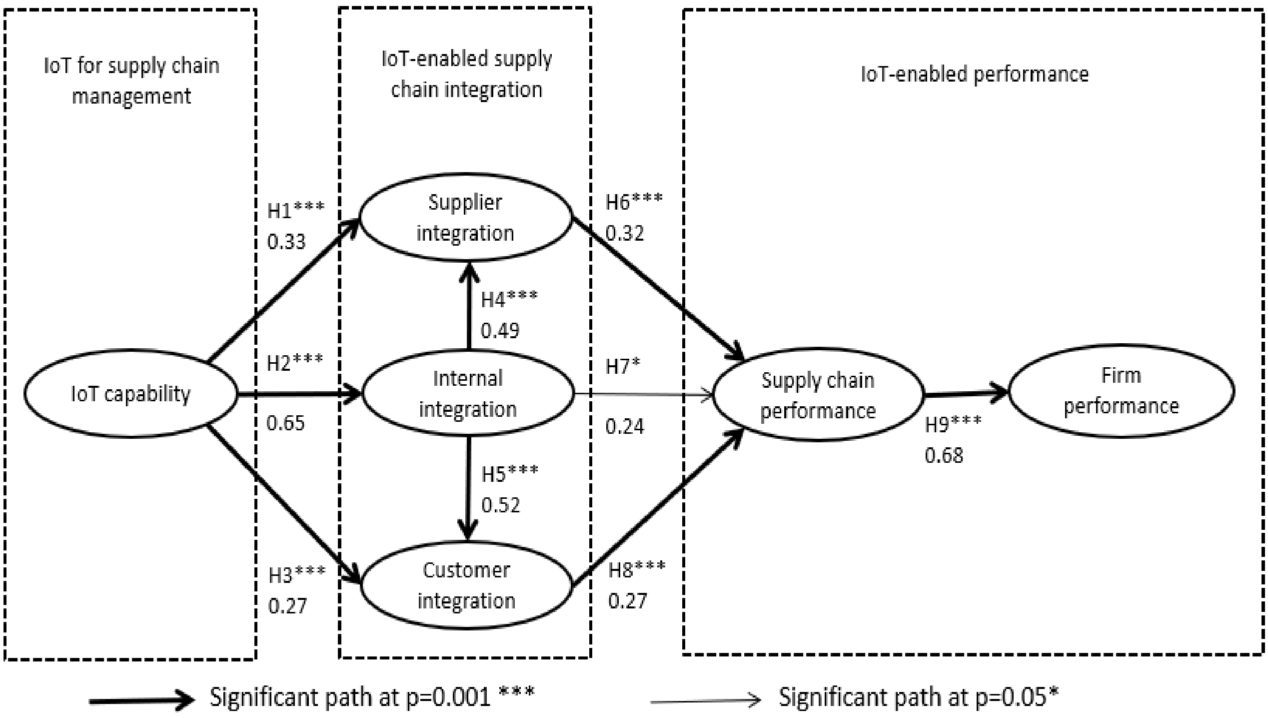


Figure 5.15 Structural model with estimated path coefficients and hypotheses

Table 5.19 Results of the structural analysis

Hypotheses	**Path**	**Std. ß**	**p-value**	**Results**
H1	**IoT capability → Supplier integration**	0.327	<0.001	Supported
H2	**IoT capability → Internal integration**	0.647	<0.001	Supported
H3	**IoT capability → Customer integration**	0.267	<0.001	Supported
H4	**Internal integration → Supplier integration**	0.493	<0.001	Supported
H5	**Internal integration → Customer integration**	0.524	<0.001	Supported
H6	**Supplier integration → Supply chain performance**	0.324	<0.001	Supported
H7	**Internal integration → Supply chain performance**	0.24	0.019	Supported*
H8	**Customer integration → Supply chain performance**	0.273	0.001	Supported
H9	**Supply chain performance → Firm performance**	0.684	<0.001	Supported

* p=.05

5.7.1 Hypotheses testing

1. Hypothesis 1 (H1) states that IoT capability has a positive effect on internal integration of logistics functions — Results indicate that IoT capability has a positive effect on internal integration of logistics functions ($ß$ = 0.327, t = 4.299, p < 0.001).
2. Hypothesis 2 (H2) states that IoT capability has a positive effect on supplier integration of business processes — Results indicate that IoT capability has a positive effect on supplier integration of business processes ($ß$ = 0.647, t = 6.285, p < 0.001).
3. Hypothesis 3 (H3) states that IoT capability has a positive effect on customer integration of business processes — Results indicate that IoT capability has a positive effect on customer integration of business processes ($ß$ = 0.267, t = 3.450, p < 0.001).
4. Hypothesis 4 (H4) states that IoT-enabled internal integration has a positive influence on IoT-enabled supplier integration — Results indicate that IoT-enabled internal integration has a positive infulence on IoT-enabled supplier integration ($ß$ = 0.493, t = 6.285, p < 0.001).
5. Hypothesis 5 (H5) states that IoT-enabled internal integration has a positive influence on IoT-enabled customer integration — Results indicate that IoT-enabled internal integration has a positive influence on IoT-enabled customer integration ($ß$ = 0.524, t = 6.374, p < 0.001).
6. Hypothesis 6 (H6) states that IoT-enabled supplier integration has a positive influence on supply chain performance — Results indicate that IoT-enabled supplier integration has a positive influence on supply chain performance ($ß$ = 0.324, t = 3.726, p < 0.001).
7. Hypothesis 7 (H7) states that IoT-enabled internal integration has a positive influence on supply chain performance — Results indicate that IoT-enabled internal integration has a positive influence on supply chain performance ($ß$ = 0.240, t = 2.349, p = 0.019).
8. Hypothesis 8 (H8) states that IoT-enabled customer integration has a positive influence on supply chain performance — Results indicate that IoT-enabled customer integration has a positive influence on supply chain performance ($ß$ = 0.273, t = 3.188, p = 0.001).
9. Hypothesis 9 (H9) states that IoT-enabled supply chain performance is positively related to firm performance — Results indicate that IoT-enabled supply chain performance is positively related to firm performance ($ß$ = 0.684, t = 8.520, p < 0.001).

The results indicated that IoT capability has a positive effect on supplier integration of retail organisations in the study (ß = 0.327, t = 4.299, $p < 0.001$). Likewise, IoT capability positively influences internal integration (ß = 0.647, t = 8.83, $p < 0.001$) and also the customer integration of retail organisations (ß = 0.267, t = 3.450, $p < 0.001$). Thus, IoT-enabled internal integration has a positive effect on both IoT-enabled supplier integration (ß = 0.493, t = 6.285, $p < 0.001$) and IoT-enabled customer integration (ß = 0.524, t = 6.374, $p < 0.001$) of retail organisations in the study. Consequently IoT-enabled supplier integration has a positive influence on the supply chain performance of retail firms (ß = 0.324, t = 3.726, $p < 0.001$). IoT-enabled internal integration also exhibits a positive influence on supply chain performance (ß = 0.240, t = 2.349, p = 0.019), however the influence in not as compelling resulting in a higher p value but falling within an acceptable range of significance at p=0.05. Furthermore, IoT-enabled customer integration displays a positive influence on supply chain performance too (ß = 0.273, t = 3.188, p = 0.001). Accordingly, IoT-enabled supply chain performance has a positive effect on the performance of retail firms in the study (ß = 0.684, t = 8.520, $p < 0.001$). By confirming all hypotheses, the findings have confirmed the theoretical model proposed in this investigation.

5.7.2 Testing the effect of control variables

Subsequent to confirming the structural theory, the structural model was tested to examine whether the control variables can have a confounding effect on the structural model and in turn the relationships. The control variables applied in the study were on firm size and retail model. Firm size, measured by the number of employees, was used as a controll, since larger firms may posses additional resources in favour of managing supply chain activities, and in consequence may gain acces to a higher level of IoT capability compared to small organisations (Rai et al. 2006; Yu 2015; Zhao et al. 2011). The classification of the Australian Bureau of Statistics for organisation size was applied to this study. However, less than 5% of the sample was small companies, while around 50% were large and 46% were medium. The organisation’s retail form was controlled because organisations conducting business differently may have a varied influence on process and technology capabilities, different intensities of IoT-enabled SCI and performance. Therefore, the retail business form of respondents in terms of bricks & mortar, multichannel or e-tail was identified. In this case, fewer than 5% of sample were from e-tail while brick and mortar represented the majority around 57% and multi-channel around 39%.

The structural model incorporating control variables was tested, but none of the control variables had any significance on performance outcomes as shown in Figure 5.16.

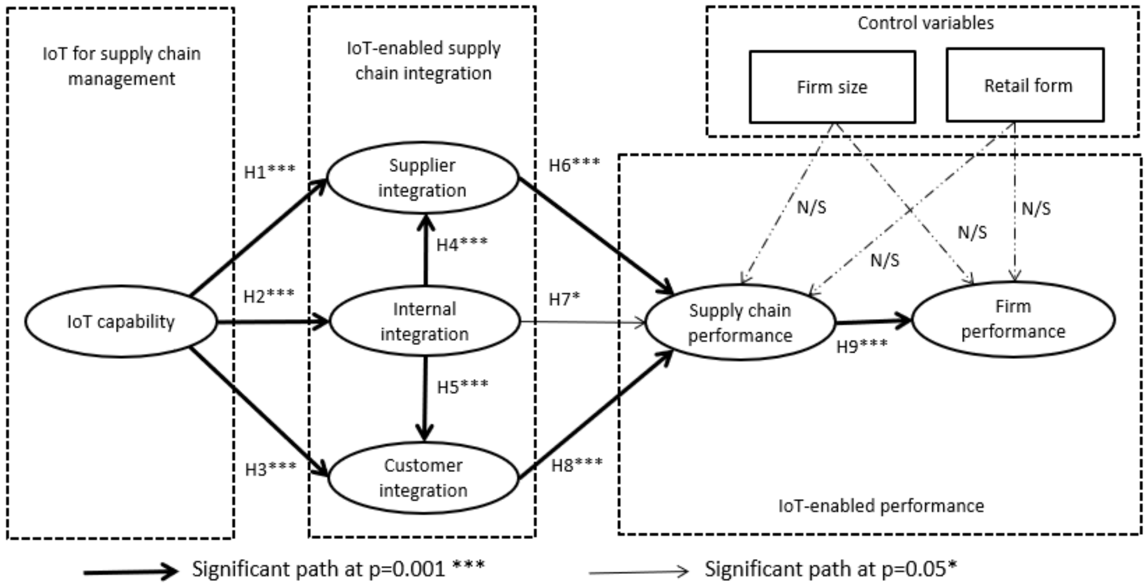


Figure 5.16 Structural model tested with control variables

The results indicated that organisation size has no significant influence on the IoT-enabled supply chain performance of retail organisations (ß = 0.167, t = 1.521, p = 0.128). The retail form also did not exhibit a significant influence on IoT-enabled supply chain performance (ß = 0.058, t = 0.881, p = 0.378). Likewise, organisation size has no significant influence on IoT-enabled firm performance of retail organisations (ß = 0.104, t = 0.968, p = 0.333). The retail form also did not exhibit a significant influence on IoT-enabled firm performance (ß = 0.09, t = 1.397, p = 0.162). Accordingly, the results indicated that the control variables do not affect IoT-enabled supply chain or firm performance, ruling out any confounding effect to confirm the internal validity of the research (Rai et al. 2006).

5.7.3 The post hoc analysis for competing model

A post hoc analysis was done to verify whether any model re-specification was possible. Any model re-specification must have not only a strong empirical support but also theoretical support (Hair et al. 2014). Given that the original theory does not cover the tested path, relationships identified post hoc are not as reliable as the original theoretical relationships (Hair et al. 2014). However, it is recommended to explore at least one non-trivial competing model, with a likelihood of representing the current literature on which the structural model is built upon, to see an evidence of improvement (Iacobucci 2010). Although the indicative measures in SEM often suggest model re-sepcification, post hoc analysis can only specify model improvement after being cross-validated by new data from the same population, that is only if there is a good theoretical justification (Hair et al. 2014). Literature confirms that ICT improves supply chain performance (Li et al. 2009; Qrunfleh & Tarafdar 2014; Shatat & Udin 2012). Qrunfleh and Tarafdar (2014) argue that supply chain response time, flexibility, delivery cycle time and product offerings etc. can be improved by ICT for performance improvement. The IoT capability, in similar argument as ICT capability in an organisation (Borgia 2014), has its key commercial application in a supply chain (Lee & Lee 2015; Riggins & Wamba 2015). IoT can monitor and improve visibility, accuracy, traceability, interoperability and collaborative decisions in supply chains (Ping et al. 2011; Reaidy et al. 2015) for greater information sharing between customers and suppliers (Lee & Lee 2015; Ping et al. 2011). This capability is perceived to facilitate supply chain decision-making (Zhang et al. 2014) leading to higher supply chain performance. IoT capability, therefore, is likely to affect supply chain performance. Hence, a direct link between IoT capability and supply chain performance was hypothesised.

Since the theoretical model propositions that the three dimensions of SCI mediate the effect of IoT-capability on supply chain operations and supply chain performance, the mediation effect was tested. The theoretical model or the main effects model that proposes full mediation by SCI was compared against a competing model that proposed both direct and mediated effects on supply chain performance. A direct path was inserted to connect IoT capability and supply chain performance. The resulting competing model is shown in Figure 5.17. The fit indices were improved from the original path model at $x^2(935)=1215.100$, $p=0.000$ and Bollen-Stine $p=0.109$, $x^2/df=1.300$, SRMR= 0.0661, RMSEA=0.036, NFI=0.832, GFI=0.806, AGFI=0.785, CFI=0.955 and TLI=0.953. The $\Delta x^2 = 21.486$ was significant ($p<0.001$).

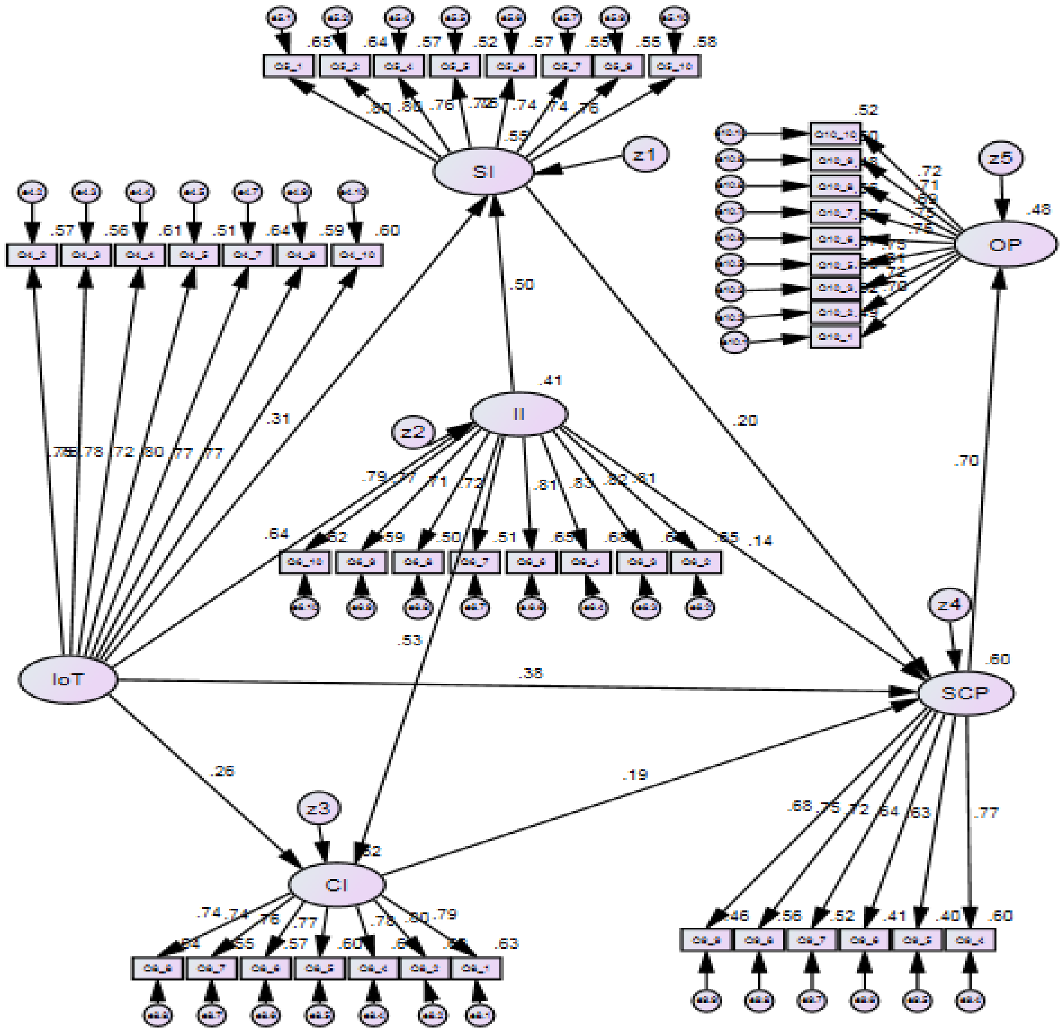


Figure 5.17 The competing/interaction model

The results indicate that the added hypothesis was affirmative, confirming that IoT capability is positively associated with supply chain performance (β = 0.379, t = 4.440, p < 0.001). Meanwhile, the strength of the relationship between IoT-enabled internal integration with IoT-enabled supplier integration (H4) and IoT-enabled customer integration (H5) were also slightly increased from β = 0.493 to 0.504 and β = 0.524 to 0.533 respectively. Likewise, the relationship between IoT-enabled supply chain performance and firm performance (H9) was slightly strengthened from β = 0.684 to 0.696). While the explained variance of supply chain performance (R^2) was increased from 53% to 60%, the explained variance of firm performance only improved from 47% to 48%.

On the other hand, the R^2 values of supplier integration, internal integration and customer integration of the competing model were reduced by one % each, from 56 to 55%, 42 to 41%

and 53 to 52% respectively. Additionally, the strength of the relationship between IoT capability with internal integration (H1), supplier integration (H2), customer integration (H3) were slightly weakened from ß = 0.327 to 313, ß = 0.647 to 0.641 and ß = 0.267 to 0.256 respectively. More prominently, the relationship between IoT-enabled supplier integration with supply chain performance (H6) was impaired from ß = 0.324 ($t = 3.726$, $p < 0.001$) to ß = 0.196 ($t = 2.279$, $p = 0.023$) and IoT-enabled customer integration with supply chain performance (H8) was impaired from ß = 0.273 ($t = 3.188$, $p = 0.001$) to ß = 0.188 ($t = 2.264$, $p = 0.024$) respectively. To make it even more unconstructive, the positive and significant relationship (ß = 0.240, $t = 2.349$, $p = 0.019$) between IoT-enabled internal integration and supply chain performance (H7) in the theoretical model was transformed to insignificant (ß = 0.139, $t = 1.419$, $p = 0.156$) in the competing model. In summary, the explained variance of integration constructs and the mediation relationship of integration constructs in the model were either moderated or severed (Byrne 2013; Hair et al. 2014).

In contrast to the competing model, IoT should ideally influence supply chain performance through its SCI mechanism (Li et al. 2009). As Rai et al (2006) argue that ICT itself cannot have a direct effect on performance; rather it needs to be blended with the organisational processes for performance improvement. Therefore, ICT capability is viewed as a lower-order/core organisational capability to enable a higher-order/dynamic organisational integration process capability for performance gains (Huo 2012; Rai et al. 2006). Li et al. (2009) study rejected the direct link to confirm that the positive effect of ICT capability on supply chain performance is through integration. This study considers IoT capability as organisational capability theory. Given that the organisational capability theory does not support a direct path and the empirical evidence is uncomplimentary to the mediation effect of integration reinforced by the theory, the direct link was considered to be unreliable (Hair et al. 2014). Adding a direct link between IoT capability and supply chain performance inflicts a detrimental effect on the mediation effect of the three integration constructs and confirms that there is no theoretical justification for model re-specification (Bagozzi & Yi 1988; Hair et al. 2014; Schumacker & Lomax 2004).

Since the models are nested, they can be statistically compared (Chin, Marcolin & Newsted 2003; Hair et al. 2014; Rai et al. 2006). One way is to compare the squared multiple correlation (R^2 values) of constructs for the competing/interaction model with the squared multiple correlation for the main-effects/theoretical model, which is minus the interaction hypothesis (Chin et al. 2003). Cohen (1988)'s f^2 was used as the effect size measure in this context. The effect of the extra path was assessed using a similar procedure to the procedure applied to test competing models in stepwise linear regression (Rai et al. 2006). The formula for computing f^2 is (R^2 partial mediation - R^2 full mediation)/(1 - R^2 partial mediation) (Cohen 1988; Rai et al. 2006). The overall effect sizes 0.02, 0.15, and 0.35 have been respectively suggested as small, moderate, and large effects (Chin et al. 2003; Cohen 1988). The R^2 for firm performance in the partially-mediated competing model was 0.48 compared to 0.47 in the fully-mediated theoretical model. Accordingly, the f^2 statistic was .01923, which was insignificant. The analysis of f^2 suggested that the additional variance explained by introducing the direct path from IoT capability to supply chain performance does not significantly add to the variance explained in the firm performance.

Given that there is no theoretical justification or a significant effect on the final performance, adding a direct path from IoT capability to supply chain performance was rejected. Exploring this critical competing model revealed no evidence of improvement to the theoretical model. The post hoc analysis concluded that no model re-specification was feasible.

5.8 Chapter Summary

This chapter illustrated the quantitative findings of the survey data. To begin with, the procedures applied to purify survey results to modify the original sample to a sample suitable for SEM analysis was discussed. Then the descriptive was analysis conducted to explain the range of respondents' demographics and technology deployment to support the suitability of the sample.

The two-stage approach to SEM was applied. Initially, the measurement model was established prior to testing the structural model. Exploratory and confirmatory factor analyses were conducted to determine the measurement items for each construct. Then the structural model was tested to confirm the hypotheses of the study.

The results confirmed the proposed theoretical model with all hypotheses (H1, H2, H3, H4, H5, H6, H7, H8 and H9) being confirmed. All except H7 were confirmed at $p = 0.001$. H7 was confirmed at a significance of p=0.05. The results suggest that in the Australia retail industry, IoT capability has a positive effect on supplier integration, internal integration and also customer integration. Correspondingly, IoT-enabled internal integration has a positive effect on both IoT-enabled supplier and customer integration. Accordingly, IoT-enabled supplier integration, internal integration and customer integration have a positive influence on supply chain performance. However, the findings suggest that the effect of IoT-enabled internal integration on supply chain performance is not perceived to be as strongly significant at the same significant level as the effect of the IoT-enabled supplier or customer integration. Fittingly, IoT-enabled supply chain performance has a positive effect on firm performance in the retail industry. The findings confirm all hypotheses and thus confirm the proposed theoretical model for the study.

The testing of the effect of two control variables on the theoretical model excluded any confounding effect to confirm the internal validity of the study. The post hoc analysis concluded that no model re-specification was possible given that there was no theoretical justification. Thus, the theoretical model was further reinforced.

The findings provide a foundation for a qualitative inquiry on a descriptive nature to verify, validate and reinforce the survey findings and the conceptual framework. The next chapter discusses the qualitative findings derived from the interviews with Australian retailers.

Chapter 6
Qualitative research findings

6.1 Introduction

This chapter presents the results of the interviews undertaken in the second phase of the study. The purpose of undertaking the interviews and subsequent analysis was to support, interpret and validate the results of the cross-sectional survey. Interviews provide an in-depth insight into the phenomenon, that is, the ground reality of how IoT deployment effect the three dimensions of SCI, and in turn supply chain and firm performance (research question two). Further, the interviews were designed to uncover the IoT technologies in use in Australian retail supply chains and the ways in which IoT technologies impacts information capture and sharing practices (research question two).

The central lines of enquiry were (a) how IoT technologies are currently deployed and used in businesses, and (b) how their capabilities are realised to strengthening supplier, internal and customer integration to impact on supply chain and firm performance.

This chapter first outlines the sample characteristics with a brief overview of the interviewed organisations in section 6.2, before moving on to the narrative discussion of the identified key themes, such as what IoT means for retailers, motives, obstacles, data capture and analysis outcomes in Australian retail supply chains in section 6.3. Section 6.4 discusses key findings on the hypothesised relationships and identified themes.

6.2 Sample characteristics

This section provides a descriptive overview of the participants from retail firms. The firms and the respondent profiles were kept confidential to protect the participants for their independent views during interviews. Table 6.1 presents a summary of the 12 retail firms and informant details (The 13th case, which is a 3PL is profiled separately in section 6.2.13). The majority of the participant retailers (7) were large (>200 employees) and the rest (5) were medium (20> & <200) under ABS classification (ABS Counts of Australian Businesses 2017). Seven retailers practiced multi-model (or omni-channel) retailing (both bricks and mortar and online); five were traditional store-based walk-in model (bricks and mortar) and one was predominantly an e-tailer. Most of them procure globally and some from East Asian manufacturing hubs, mainly from China, as well as local manufacturers. There was a good mix of retail sectors covering all ABS retail subdivisions and sectors used in the survey (ABS Retail industry analysis 2014; ABS_ANZSIC 2013). All respondents were managers with adequate working knowledge of technology application in supply chain management and had served over 2 years with their respective firms.

Table 6.1 Summary profile of the retailers participated in interviews

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

6.2.1 Retailer A

Retailer A is a medium sized social enterprise in the cosmetic and toiletry sector practicing a multi-model retail form. The participating supply chain manager possesses over 10 years of retail experience and has worked for over 2 years for the focal retailer. The entire supply chain operations including procurement come under the informants' purview while warehousing and transportation are managed through 3PLs. Its supply networks span globally, but most merchandise is locally manufactured. Retailer A previously had an antiquated system, but they first adopted IoT in the supply chain less than 2 years ago for upgrading their IT system. The respondent described that they have had a 'pretty clunky' supply chain, purely because of the infancy of the business and the level of growth that has happened in the last 12 months. The respondent believed that IoT deployment in their supply chain is in its infancy, and "far-off" of the potential efficiency and streamlining that can be achieved via IoT.

6.2.2 Retailer B

Retailer B is one of the largest department store chains in Australia, limited to the bricks and mortar retail form. The supply chain manager interviewed has 11 years managerial experience with the focal firm. Retailer B focuses on the upstream side of the supply chain, but mostly concentrates on low-cost regional manufacturing hubs. Its logistics functions are inclusive of overseas distribution centres (DCs). Shipping operations are managed by 3PLs. The informant believes that they were one of the early adopters of IoT, deploying over 11 years ago to support their supply chain functionalities. The respondent believes that, with reference to in-shop technology, they are not current with IoT, but when it comes to the DCs, they have a state-of-the-art operation in Australia.

6.2.3 Retailer C

Retailer C is one of the largest global supermarket chains in Australia with predominantly bricks and mortar retailing. The informant is a supply chain manager with over 8 years of experience in retailing and has worked for the focal retailer for 3 years in the current role, with a key focus on operational process improvement. Having a globe spanning supply chain, its local warehouses (DCs) are managed in-house, but the majority of transportation is operated through 3PLs. The informant was not sure exactly when they first adopted IoT in their supply chain but stated that it would have been when they reinvigorated the transference to technology adoption around 4 years ago. They have recently restricted any technology upgrades for an anticipated state-of-the-art project to be soon rolled out (unspecified in the interview).

6.2.4 Retailer D

Retailer D is a large leading pet products retailer practicing a multi-model retail form. The interviewed supply chain manager has over 2 years of experience in the current role. The entire supply chain operations including procurement is overseen by the informant. Its warehousing and transportation operations are outsourced to 3PLs. Its supply networks span globally with the majority located in India, China, the US and Australia, and they also export. The informant believed that they are late adopters, just starting to adopt IoT technologies, but estimated that their transporters have been using IoT for the last 5 years at least.

6.2.5 Retailer E

Retailer E is a medium-sized firm from the restaurant/café/takeaway sector. It practices a multifaceted multi-model approach, where its customers can eat in or take away by ordering in person, or eat in, take away or get food delivered by ordering over the phone or online. The owner-informant has managed the overall operations for the past 3 years. Its immediate suppliers are all local. They deployed IoT around 3 years ago in their supply chain operations. The respondent believes that there is good progression in their sector with a lot of new IoT solutions introduced and managed via third party apps running as 4PLs, especially in customer ordering and delivery functions.

6.2.6 Retailer F

Retailer F is one of the largest telecommunication service providers in Australia who engages in electronic and telecommunication product vending coupled with its services. It conducts both online and store-based retailing. The informant is a supply chain manager overseeing the product network and has been in the current role for around 4 years. Despite products being mainly imported from East Asia, its immediate supplier manages all its logistic functions from store delivery to customer delivery by operating as a 4PL. The informant believes, having first implemented IoT is their supply chain over 3 years ago at least, that they still have very basic versions of IoT with most of the technologies being computer-based; their logistic service providers are using IoT better. The respondent does not think they have invested in the product supply chain as much as they should have, and that it is ‘rudimental’. It was mentioned that their competitors were a lot more advanced in IoT and they also have heaps of potential in IoT space, but the organisation is reluctant to invest on the product side of business because the market tends to shrink.

6.2.7 Retailer G

Retailer G is a leading global clothing, footwear and personal accessories retailer practicing multi-model retail form. It has a robust global supply network for over 3000 product offerings, with new seasonal products introduced in every 3 months. The participating manager has been overseeing its upstream supply chain operations for around 5 years. Its local warehousing and transportation operations are outsourced to 3PLs, while the e-tail segment is run from overseas as one central global operation. The informant believes that they are at the forefront of innovation, so it could be one of the first to use IoT, and assumes that they have made use of IoT from the day it was commercially available (over 15 years ago) given that it is a company of global operations. They have been very progressive with IoT adoption and believe "whatever is available is used in some part of the supply chain".

6.2.8 Retailer H

Retailer H is a medium sized firm from motor vehicles parts and electronic product retailer. It has just few stores, but a large portion of its sales are conducted online. Retailer H operates from one large central warehouse. The respondent is the IT manager, who has worked for the company for the past 10 years and is responsible for overall IT functionalities of the establishment with a key focus on the warehouse management system. It has a global supply network with the majority of the suppliers coming from China. Retailer H has only been looking at IoT deployment in their warehousing operations in the past 3 years, but it is estimated that their 3PLs, who manage both inbound and outbound transport operations, have been using IoT for the past five years at least. The respondent admitted that initially they were a bit cynical about the technologies, but then they have started growing the trust in IoT technology.

6.2.9 Retailer I

Retailer I is one of the largest supermarket chains in Australia with multimodal practices, but predominantly established as a store-based FMCG retailer. Retailer I has a very large robust global supply network and its widespread domestic warehousing and transportation network is managed through 3PLs. The participating supply chain manager oversees the upstream side of the supply chain with a sustainability focus. The respondent, who has been in the current role for over 5 years, is proficient in examining supply chains through a lens of human environmental outcomes. They first deployed IoT in their supply chain over 10 years ago at least but have been looking at IoT deployment seriously in the last 5 to 7 years.

6.2.10 Retailer J

Retailer J is a large popular operator in fuel and convenience stores sector practicing bricks and mortar retail form. The store manager has worked for over 20 years for the establishment, and only deals with local first tier suppliers. The fuel supply comes through its global supply chain and local transportation is managed by 3PLs. The consumer goods are delivered to the store by local suppliers. The informant, who has observed its technology adoption for over two decades, believes they first adopted IoT in the supply chain in the last 5 years. The respondent believes that still there is a lot to be done with IoT technologies in their supply chain operations.

6.2.11 Retailer K

Retailer K is a medium-sized firm in the electronics sector dealing with image recognition, security and surveillance, most products possessing IoT capabilities. It practices a multi-modal retail form that involves e-tail, a showroom and sales personnel visiting houses and establishments to promote the product (direct-sales). The head of IT interviewed has managerial experience of 5 years with the focal firm. Their supply networks are from East Asian regional manufacturing hubs. They work with one immediate supplier, and it is that the suppliers' responsibility to get the product to them. Almost all its logistics functions are managed by 3PLs. The informant believes that their IoT adoption dates back 3 years, but their 3PLs have used IoT for around 5 years to support their supply chain functionalities. However, the respondent admits that capitalisation on the present-day IoT potential for their supply chain operation is somewhat minimal, and the reason they are behind is that their operation model does not require such technology at this stage.

6.2.12 Retailer L

Retailer H is a medium-sized firm from the household goods sector. It has just one shop adjacent to their main office, but most of its sales is conducted as an e-tailer. The respondent is the General Manager, who has been with Retailer L for the past 7 years. The majority of its products are manufactured and procured locally with about a quarter of supplies coming from China. The Australian operation manages supply for their international hubs as well. Their first IoT deployment in the supply chain was approximately 6 years ago in logistics management by their 3PLs. Retailer L stated that their operation is mainly conducted manually and is not the best example for a good efficient operation. The respondent reiterated that their ability to make the next step in terms of digital online perspective gets pushed down in the priorities of the business.

6.2.13 3PL X

The 3PL X is one of Australia's largest third-party logistic service providers and has a huge retail clientele including leading supermarket chains, department stores, and clothing brands. They manage outsourced warehouse and distribution centre (DCs) management as well as transportation management for their clients. The participant oversees field technology deployment and practice for those in logistics operations. The respondent has been working for the current 3PL for about four years and in the supply chain industry for two years prior. The informant believes that they first adopted IoT into their operations from the transportation perspective, back in 2005/6, while GPS telemetry was adopted in 2007, and warehouse management systems dated back to the mid-90s. They claim they are an early IoT adopter but haven't done much for long time. Therefore, they are currently investing heavily to stay at par with industry. The interviewee expressed his concern about the return on investment of IoT technologies where contract logistics continue for 3 or 5-years. Note that the earliest IoT deployment recorded was by 3PL X in warehouse management systems in the mid 1990s.

6.3 The emergence and prevalence of the IoT in Australian Retail

6.3.1 How IoT is understood

All thirteen managers had a good understanding of what IoT means and were harmonised with general definitions from the literature:

> "IoT for me is things that are connected anywhere anytime, that you can access when you want, where you want" [3PL X].

> “It is an umbrella term used universally for the mechanics behind it, devices capitalising the power of Internet” [Retailer I].
>
> “IoT is the reasons that we can have the device here but run the brain in the Internet.” [Retailer H].

Retailer K explained the current position,

> “When it comes to IoT, it is still at a very primitive stage, it is getting there. However, the world doesn’t realise it as IoT. Knowingly or unknowingly, there are at least 1 or 2 ‘Internet touch points’ on you all the time. Everyone nowadays carries a smartphone, an IoT device which is always connected to the Internet”.

Retailer K discussed the benefits from Internet connectivity to such devices.

> “Most of the programs are too big to run on ‘edge’ (run on the device itself), therefore run in the Cloud. IoT platform reallocates analytics from the edge to the Cloud. It can communicate instantaneously, update all devices remotely, get the information from anywhere in real-time. That’s the advantage of IoT”.

IoT was conveyed as a part of a broader ICT infrastructure by all thirteen interviewed. Notably, all respondents referred IoT as a familiar technology with an own separate identity.

> “As a technology IoT is getting into the Australian market these days. The market these days as we see now is mature enough to understand about IoT” [Retailer K].

Six retailers stated that traditional ICT is insufficient within the present business context.

> “The email and phone conversations to raise orders is not so adequate for planning and transparency” [Retailer A].

6.3.2 The status of IoT deployment

All respondents believed that IoT had existed in their supply chain for at least the past two years in some form. However, some thought they were somewhat further ahead in IoT deployment than their competitors (Retailer G, E, H) and some thought they were behind (Retailer A, F, L). Most believed that they had IoT in place to a reasonable degree, as a mix of ‘things’ across the supply chain, in different operations at different intensities.

Retailer G reflected that, as the market leader, it is important for them to stay ahead in the competition, therefore they are keen to invest in a technology like IoT.

On the other hand, Retailer L stated that some of their restrictions in competing with larger retailers are in terms of technology as larger retailers are so much more developed in IoT deployment.

Similarly, some Retailers (B, G, E) mentioned that they embraced IoT almost instantaneously, while some (C, H) observed others before jumping on board, and others lagging behind due to various reasons (A, F, I).

Many referred to the retail industry as "very competitive" and IoT as a technology that can help them gain a sustainable competitive edge.

> "You have to have an excellent supply chain, because there is so much competition. That's where IoT comes in to play" [Retailer L].

6.3.3 How IoT is perceived in retail supply chins

Consequently, all 13 managers agreed on the value of IoT in supply chain operations.

> "At the end of the day, supply chain management is all about connecting the dots. So, I think there is a definite need for IoT. Tracking, picking, and processing can be streamlined" [Retailer A].

> "I believe IoT has an epic potential in supply chain operations" [Retailer C].

> "We all know that the benefits are there, you don't actually have to sell IoT technology, that everybody understands why you should be doing it and the benefits you get" [3PL X].

Eight managers specifically stated that IoT in general is a sound investment.

> "The cost will pretty much offset itself, in say maximum of 3 years into operation [Retailer E].

The common sentiment is that they would like to explore IoT's potential.

> "Such technology that makes our supply chain smarter and faster, we would look at it in positive eyes [sic]" [Retailer B].

> "I think it is important to understand the effect of this (IoT) technology on the supply chain" [Retailer K].

6.3.4 Position of RFID within the IoT context

Eight retailers identified that RFID was an early form of IoT:

> "I recall talking about RFID technology 20 years ago" [Retailer I].

Item level identification via RFID has not come into full fruition yet.

The cost was the key constraint.

> "RFID tagging and tracking of low-cost FMCG products still seems quite expensive" [Retailer I].

Both open and closed standard barcoding seem to be the preferred and cheaper option for many, while image recognition was also discussed by Retailer H and I as a developing alternative for product identification (Satapathy et al. 2015). Only Retailer G had immediate item level RFID plans. Retailer J reported that they had being doing some testing, but none of the others had any proximate strategies of implementing RFID for item level identification.

6.3.5 Existing IoT technologies and forms in Retail supply chains

The findings suggest that in practice, many technologies that come under the umbrella of IoT technologies coexist in Australian retail supply chains, providing added digital capabilities. Few use RFID on the unit level (i.e. pallet, container) in warehousing and transportation. A barcode scenario has enabled a simpler deployment of IoT (Suresh et al. 2014). Barcodes scanners, PDAs (personal digital assistants), RF (radio frequency) scanners, laser and LED scanners and camera-based scanners are widespread in retail supply chains.

In the warehousing environment, when the customer orders are received to the warehouse, the handheld devices (e.g., PDAs, RF scanners) that receive and communicate the order provide a picking order, confirm the product by scanning to ensure it is the right product, and confirm the picking.

> "When the order is received to the warehouse those hand-held devices that the order is pushed into that would provide a picking order, tell you the location by the product, conform the product by scanning to ensure it is the right product that has been pick and to confirm the product has been picked. It is more efficient than going there, there, there [sic], which is pretty clever. The timings of the orders are rapidly condensed if you can imagine the system is smart enough to tell you where which location is the best way" [Retailer A].

Additionally, voice pick to help picking, automatic guided vehicles (AGV), and automatic pallet movers or conveyor control systems are in use. In the retail store environment, handheld devices, POS devices, handheld sensors, video analytics (facial recognition for customer recognition and context-aware offers), IP Cameras, barcoding (unique for some perishable items) and mobile payments, including Apple Pay, are currently in use.

> "The deliverers are using IoT technology to find the best routs, avoid traffic and to also help us improve our service standards" [Retailer C].

In transport, IoT-enabled track and trace systems, fleet controlling, vehicle tracking, fleet tracking systems, route optimisation and route consideration are used. IoT retina scanners and facial recognition in the trucks can monitor driver fatigue by tracking pupil size, eye blink frequency and driver behaviour. IoT in fleet management can monitor how often a truck is in use or idle by analysing the transmitted GPS data to enable optimal utilisation. IoT based sensor networks in cold chain logistics track and trace transported and stored temperature-sensitive products. GPS tracking system via smartphones in food delivery, such as UberEATS, allows the customers to order, pay for and track the delivery status of foods.

Therefore, as per interview findings, there are a large number of forms of industrial IoT used in Australian retail supply chains. Although IoT technologies are at the early stages of development, they seem to provide additional capabilities to legacy ICT infrastructure to capture and transfer data and automation in retail supply chain.

6.3.6 Drivers for IoT in retail supply chains

The recent advancement of IoT in retail was attributed to four trends: advancement of the Internet, reduced device cost, Gen Y as customers and employees, and the proliferation of personal mobile devices. These trends are discussed in-depth below.

Eight participants, including 3 managers from an IT background, articulated that improved Internet speed has enabled IoT to emerge strongly within the past decade and become progressively more accessible and affordable, enabling its widespread deployment.

> "The Internet is better, and the prices are continuously going down" [Retailer E].

The second trend is the presence of Gen Y in organisations and as customers. Young people, known as Generation Y are much more comfortable using such technologies for the best outcomes (Tapscott 2008). Accordingly, Gen Y, as a driver for IoT deployment at personal and industry environment, was discussed by six retailers.

> "Because they are all Gen Y, they are fast adaptors. Every little bit of technology you bring in, they are straight on" [Retailer D].
>
> "Most of them are young people, so they love these kinds of apps. I'm talking about customers and staff both" [Retailer E].

The third and most discussed driver was the proliferation and use of personal IoT devices. Eight managers agreed that there was substantial proliferation of IoT as a personal application that stimulated IoT's applications in industry. Mobile phones, being an integral part of everyday life, play a key role in bringing "ubiquitous" communication technologies to the mass market (Porkodi & Bhuvaneswari 2014).

> “This evolution of the mobile has done big things. It's more like a mini computer now” [Retailer H].

Despite being a personal device, all thirteen managers spoke of smartphones as a tool to help integrate supply chains either as an operative or as a customer. Retailer D discussed the smartphone via an app advising on operational data for staff members and an app for customers. Retailer E reported that smartphone apps have revolutionised the restaurant industry by operating as 4PLs connecting customers and deliverers. 3PL X provides their contracted drivers with a smartphone application for tracking purposes, to optimise routes and to communicate instructions digitally. Retailer G echoed the influence of smartphone apps that inform their customers on fitness activities, remind them when their shoes need replacing and allow them to purchase a new pair.

Smartphone apps such as Uber, UberEATS, Google Maps, fitness apps, TV remote apps and appliances such as smart watches, Fitbits, Google Home, security cameras, trackers and medical monitors were cited as personal IoT applications.

6.3.7 Motives for IoT deployment

The key theme identified as a motive for IoT deployment was efficiency, supported by 9 managers through interviews.

> “Because it enables an efficiency, in terms of movement of goods in the supply chain” [Retailer A].

Within the efficiency theme, time saving was cited as a motive by 6 managers. Reduction of manual work was a motive for 6 managers. Relatedly 4 managers cited productivity as a reason. Retailer J pointed to speed. Process optimisation was mentioned by 4 retailers. Cost minimisation was cited by 3 managers.

Six managers revealed visibility as a key motive.

> “To get access to information and the visibility of information” [Retailer D].

Relatedly, 6 managers specified real-time data.

> “As a business having access to information in real-time capacity” [Retailer L].

Three managers spoke on the theme of getting more data to help decision making.

Accuracy was also mentioned by 3 respondents.

> “Accuracy of data is obviously better when a device is doing it for you rather than a human” [Retailer H].

Three managers cited security and surveillance. Three retailers mentioned customer satisfaction as a motive, while 3 retailers mentioned it as the industry standard,

> "We are forced into these things because of the retail requirement" [Retailer A].

Having connectivity to have remote access was discussed by 3 retailers.

The 3PL X likewise cited efficiency, visibility, check history, speed, data, reduced costs and saving time as motives, but stated, "Aside from safety, the end goal is you keep the contract".

6.3.8 How organisational structure influences IoT implementation decisions

Nine managers discussed how their organisational nature effects the IoT deployment decision-making. However, the rationales were different and inconsistent. Retailer C stated that, given they are a multinational, they are expecting a state-of-the-art roll out. Retailer G was on a similar line asserting, as a global company and a market leader, they are at the forefront of innovation. Retailer I in FMCG referred to the nature of their product as a decisive factor. Retailer L believed that their products arriving into the warehouse in components was a key issue in deterring IoT implementation decision. Retailer E referred to the customers' expectations of the restaurant industry as a key influencing factor, thus "smartphone apps are almost a necessity and a standard". Retailer A and D cited the age of the firm as affecting IoT adoption. Retailer L referred to the effect of firm size and age. Retailer D viewed the negative potential of their market as the key consideration factor, and they "don't want to invest on a shrinking market".

3PL X reported that it is their customers' (retailers) demand that is the key influence in them having such technology in place, and complained,

> "They go all the way to the trouble to make sure we have it, then we provide it to them, but they never use it".

6.3.9 The role of 3PLs in retail supply chains and IoT adoption

All 12 retailers outsourced a major part of their logistics functions. All of them had inbound and outbound transport logistics outsourced to specialised 3PL providers. Only Retailer C had a small fleet of their own trucks used for replenishment of retail stores. Retailers K, E and F used a fourth-party logistics (4PL) model of outsourcing. Eight of them had their warehousing/DCs run by 3PLs. Ten retailers reported low cost as the key motive for outsourcing. Alternatively, 4 cited the timeliness of service as the key motive.

Apart from some early adopters such as Retailers B, G, I, most respondents articulated that their first IoT experience in supply chain operation was in fact through 3PL transporters, which was corroborated by 3PL X, having IoT since 2005 in their haulage systems, and in their warehouse management systems since the mid-1990s.

Incidentally, 7 retailers considered technological aptitude to be a key criterion for 3PL selection. For example, 3PL X uses many IoT forms in its haulage operation. Some in-cabin IoT technologies are GPS receivers with driver identification to produce a track and trace history, vehicle tracking, speeding information, route optimisation systems, fleet controlling, route consideration, duress alarms, man down pendants, video camera, smartphones, sensors to remotely monitor temperature for chilled freight in cold chain logistics, IoT retina scanners in the trucks that can monitor driver fatigue by tracking pupil size and blink frequency, and facial recognition cameras. IoT in fleet management can monitor how often a truck is in use or idle by analysing the transmitted GPS data to enable optimal utilisation. Apart from that, they can also transmit data of electronic braking systems in the truck and trailer to know how many kilometres are done to help in maintenance, engine management systems where they can get reeds of the engine. The drives also use "sign on glass" instead of paper and use handheld devices for scanning.

All 12 retailers mentioned having the IoT enabled systems of their 3PLs integrated into their processes, for example tracking an inbound movement or customers tracking their deliveries. In fact, Retailer A, E, K and L unequivocally mentioned saving on investment in such technologies due to outsourcing. 3PL X confirmed above notion, stating they probably had won many contracts because of their technology capability and others they have lost because they didn't have the right technology implemented. 3PL X reiterated that lot of the technology they put in, apart from wanting to keep their people safe, is to keep customers happy. Six retailers reported that the 3PL industry is very competitive; therefore, they need to use every technological boost possible. Eight respondents suggested that harvesting the potential of IoT is a factor for 3PLs being able to reduce their fees. However, 3PL X stated that IoT does reduce the cost in the long run, but the end goal of such technology deployment as IoT is to retain the contract. The manager further reiterated that not having long-term contracts hinders technological deployment in 3PL space due to concerns about the return on investment.

6.3.10 IoT for SCI

The theme of SCI was positively discussed as a general means to improve respective operations by 11 of the retail respondents and 3PL X. [2] All thirteen articulated IoT as a valuable tool with potential to further integrate their respective supply chains. However, in many discussions, IoT was referred to as a tool to *improve processes, rather than having a direct effect on performance*.

> "IoT for me is a technology that enhances the communication within the supply chain and gets the integration better" [Retailer C].

Despite the benefits, five believed that their supply chain was not as well integrated as they would like.

> "Our issue is not having that integration; we have no visibility in how the customer has been served" [Retailer F].

Retailer D while acknowledging IoT as a great platform to integrate business processes stated that, "oral communication matters more than the technology and technology is just a tool to help us".

6.3.11 Data capture and analysis

The role of data capture and analysis facilitated by IoT is vital to this assessment, particularly when compared to traditional ICT. This direct comparison was made by 7 managers. Ten managers confirmed the benefits and outcomes of analysing the data captured by IoT.

> "Capturing of the data that we didn't have access to before is a massive opportunity we have with IoT" [Retailer H].
>
> "Having this technology is purely information. As an analyst the depth and the effectiveness of your analysis is always limited by your data. So, more data you have, and the better data to have the better [3PL X].

IoT data analysis findings is utilised in many areas of operation including forecasting and planning, understanding customer needs, operational, tactical and strategic decision-making, evaluation of staff, instruments and processes, auto reporting and ordering, and process improvement.

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[2] Retailer K, who thought their operation model does not require them to work closely with external parties, still expressed that integration is a common strategy in many successful supply chain ventures.

While 7 managers discussed reporting as a key improvement caused by IoT, 5 spoke specifically on the advantages of real-time analytics and reporting.

> "Streamlining of reports is immediate. Managers can see these statics live and take decisions. But if you don't have these IoT devices integrated, it will take weeks or months. By the time you realise issues, it's too late" [Retailer H].

Correspondingly, Retailer I stated, "real-time reporting and inventory management is the primary driver for us to implement IoT". Real-time streaming analytics is a major feature of prevailing IoT platforms (Ahlgren et al. 2016).

Moreover, while acknowledging the benefits, 3 managers cautioned on the volume and complexity of IoT data.

6.3.12 Information Sharing

While no firm shared captured raw data, 10 managers reflected on analysing the data in-house and sharing the findings with supply chain partners for the purposes of evaluation, planning, forecasting and process improvement.

> "We don't share data with our supply chain partners, we just share the outcome. We don't want to expose data. Sharing of findings has helped us improve our processes" [Retailer H].

Six retailers specifically spoke of sharing the findings with suppliers.

> "The supplier is waiting for that visibility in the planning process. We provide visibility to the supplier 2 years in advance" [Retailer G].

Retailers B, D, F, I gave some of their suppliers' real-time access to some specific data. Out of which Retailer F's supplier, acting as a 4PL, is integrated to the retailer's system. Retailer D provides access to respective point of sale data to key suppliers via an app. For Retailer B, only very specific suppliers have access to their respective stocks in stores, so that the vendors can fulfil the stock at the stores. Retailer I also has a vendor-managed inventory model for certain products, but has the suppliers' representatives positioned at the retailer's head office to gain access to the system. In terms of reverse sharing, only Retailers E and F spoke of suppliers sharing findings with retailers.

In contrast, 6 retailers discussed in-house cross-functional sharing of both data and findings.[3]

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[3] Retailer A reiterated that managers get bored with supply chain data and are more interested in products, brand and marketing than getting the product to the customer.

"IoT data is pretty much shared with all functional teams" [Retailer A].

For example, Retailer D explained their real-time analytical tool displaying key information to all managers via a smartphone app.

Seven retailers discussed transporters sharing analysis findings with them.

> "They (transporters) always provide us with reports on outcomes, their success rate and such" [Retailer L].

Nine retailers had portal access to at least one tracking system either upstream or downstream.

6.3.13 Obstacles for IoT adoption

The obstacles that negatively affect IoT implementation decisions include: the cost of investment, a lack of understanding in the technology, lack of management support, resistance to change, fear about the technology, privacy and data security concerns, learning time and capabilities of individuals.

The main obstacle was the cost of investment as cited by 11 managers.

> "The cost is obviously the really big obstacle" [Retailer L].

Retailers B and I mentioned that it is not fair that upstream suppliers and manufacturers have to bear the cost of technology such as RFID, yet the dominant downstream partners realise the return. Retailer I called for collective investment.

> "It is a space where retailers and brand owners need to invest together to impart capacity capability improvements".

The second frequently featured obstacle was the technology being not well understood, cited by 7 retailers.

> "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 thought lack of management vision and champions is hindering IoT adoption.

> "I think it is the management who are a little bit cumbersome when it comes to things like this" [Retailer D].

Retailer I mentioned not having advocates within the business who have had experience and are able to say, "it's great and I want to bring it in".

Four retailers found higher managers did not understand the demands of supply chains. Alarmingly, Retailer I stated that, "managers don't want to know up the value chain, it is easy to kind of disguise what is happening upstream, which is beneficial to the organisation".

Six cited employee resistance to change as a reason.

> "It's human behaviour, people are reluctant to change" [Retailer L].

Relatedly, staff members fearing technology was mentioned by 6 retailers.

Privacy and security issues were also raised by 6, particularly in relation to consumer side apps.

> "People are nervous of where your data is going to sit" [Retailer H]

Time to learn and adopt to new technology was mentioned by 4 as an obstacle in IoT implementation decisions. Internet reliability was a concern. Three retailers cited Internet breakdown as a concern, while another 3 mentioned coverage issues. Retailer L questioned technicality of "the integration capabilities of existing systems".

6.3.14 Constraints in capitalising implemented IoT

Not being able to make enough time and effort to learn their newly introduced IoT technology was considered the key constraint to make the best out of existing IoT technology in the organisation, as discussed by 8 retailers.

> "A huge time need to be a spent-on training yourself first and understanding, and then the training of staff and the third-party providers. I think that would be the major challenge in IoT adoption" [Retailer C].

On the contrary Retailer D stated that "We gotta [sic] very young team, because of that, we were able to adapt quickly".

The older generation's resistance was the second strongest theme, discussed by 6 managers.

> "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].

The similar theme of reluctance to change was also mentioned by 5 managers. Retailer D remark on laziness to adopt to new things as, "people are inherently lazy".

The other frequent theme discussed by 5 managers is the constraint of Internet service quality.

People not understanding the benefits of IoT was also discussed by 3 managers.

> "The biggest issue with getting the best outcome of the technology is that probably people are not educated enough to understand the influence of it" [Retailer G].

Being scared of sharing information as a constrain to capitalise on IoT deployment was discussed by 4 managers.

> "Most of the time they fear sharing. That is the biggest killer for us and for IoT as a technology" [Retailer H].

Furthermore, not being able to properly understand IoT data was discussed as a restriction to making the most out of IoT by 3 managers.

"It's a lot about understanding data, being able to digest the analytics" [Retailer B].

Relatedly, Retailer H cited the complexity of having various identification technologies.

"RFID, QR codes, barcode, NFC, we have to be ready for all that".

6.3.15 Interoperability, openness and standardisation issues

Interoperability and openness among platforms and standardisation were reported to be central issues among stakeholders within the IoT architecture (Ahlgren et al. 2016; Atzori et al. 2010). Correspondingly, not having access to the systems of (some of) their supply chain partners was an issue mentioned by 5 retailers.

"If we could log into the portal of the shipper to track and trace, that saves us picking up the phone, calling, having a 20-minute conversation" [Retailer A].

Also, having access to partner systems, but still not having that system integrated to their own system was also discussed by 3 retailers.

"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 be a singular experience for the customer" [Retailer L].

Having to log in too many interfaces each time as "systems not being interconnected (silo)" was discussed by 3 respondents. Retailer I expressed a major issue faced by suppliers having to comply with the inefficient process of managing diverse ICT (and IoT) forms and platforms preferred by each retailer and brand owner and argued for "collaboration on one agreed platform".

Eight retailers discussed the theme of standardisation. Some (4) discussed the issue of not being able to integrate systems due to a lack of standardisation. Four retailers indicated resistance in tolerating diverse standards of identification technologies, and open and closed standards. Retailer C talked about having multiple closed standard barcodes.

"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".

GS1[4] open standard, cited by 5 retailers in the discussion, could be the solution.

[4] EPC-based RFID tags, barcodes, IPv4 or IPv6 standards, the GS1 system of standards and services is a key enabler of IoT dissemination (GS1 2016). Such open standards enable interoperability among infrastructure, systems and hardware (DeNardis 2011).

6.3.16 Drive for consolidation

In keeping with the caution in adopting the technology, there is a drive to exploit those built-in capabilities of widespread smartphones, rather than having many IoT devices for different purposes, a theme discussed by five managers.

"The trend now is using the same device for all purposes" [Retailer H].

Given the prominence of smartphones that are inevitably carried by individuals and are part of their natural ecosystem, there seem to be a drive to piggyback on its resources as the central integration device. Retailer H explained their drive to substitute the functionality of handheld devices to smartphones in their DC. Retailer G stated that chips (sensors) in the sole of the shoe was not necessary anymore 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 each, towards the use of a single SIM card connecting all devices through the smartphone.

6.3.17 An overview of IoT in Australian retail supply chains

This section presented contextual information about IoT deployment in Australian retail supply chains. All participating managers were familiar with IoT technologies and their use. Likewise, they consistently referred to IoT as an element of ICT, with additional capabilities (Atzori et al. 2010; Borgia 2014).

It is evident that there are many innovative technologies currently in existence in Australian retail supply chains. The affordability of its fundamental technologies, the Internet's expanded coverage and transmission rates reaching impressive speeds has enabled present IoT proliferation. The presence of Gen Y as customers and employees and the abundance of IoT personal devices were found to be key drivers for IoT application in retail supply chains. Gen Ys influence on IoT deployment in supply chains is rarely reported elsewhere. While efficiency and real-time data were considered to be key motives, it was found that the firm's nature affected the IoT deployment decision inconsistently. Importantly, all firms are dependent on 3PLs for a greater part of logistics. They consider 3PLs to be forerunners in IoT deployment, thus retrieving IoT capabilities from 3PLs is a commonly reported strategy.

The concept of SCI was discussed directly or indirectly, where participants referred to IoT as an effective means for integration. The managers agreed on the importance of IoT for data capture but shared only the findings, not the data, with external partners. Managers found cost to be the key obstacle for IoT implementation in supply chains yet consider it to be a sound investment.

6.4 IoT-enabled supply chain integration and performance – the hypothesised relationships

This section presents qualitative findings to help interpret and validate the quantitative findings from the survey. It will validate the extent to which IoT technologies in Australian retail supply chains are able to help integrate internal and external logistics processes. Additionally, it explains and validates the impact of IoT-enabled SCI on supply chain and firm sustainable performance. By doing so, this section attempts to answer the research question two by examining the ground reality of how IoT deployment effect the three dimensions of SCI, and in turn performance.

6.4.1 How IoT helps in supplier integration

The characteristics of the procurement processes were subjective to the operational nature of each retailer. Thus, the approaches to integration and how IoT was applied for it were diverse. However, each respondent perceived IoT to be influencing their integration with supplier positively and improving supply chain performance.

> "I think IoT application can improve communication, information collection and sharing with upstream partners for sure" [Retailer A].

This section discusses how various IoT forms co-exist to strengthen supplier integration processes. The key themes were supplier operational improvement, communication, forecasting, inbound delivery and receiving and traceability.

6.4.1.1 IoT deployment by suppliers to better satisfy retailers need

How IoT integration help their suppliers to better fulfil retailers' requirements was discussed by 10 retailers. Discussion implies that IoT deployment intensity is very subjective to each supplier.

> "You may be surprised how advanced their technologies are, lots of IoT, all automated. Because of the amount of despatch they do per day" [Retailer H].

Retailers described many IoT forms at the supplier end to improve their own processes, that in turn to help the retail. The handheld devices, scanners, labellers, QR codes, barcodes, NFC, smartphones, tablets, various sensors in manufacturing and warehousing environments, image recognition, scan picking, and voice picking were some of the common IoT forms mentioned. Retailer H explained how one of their supplier warehouses performs picking using automatic guided vehicle (AGV) systems, automatic pallet movers and conveyor control systems and how it has "massively improved the delivery times". It was explained how their stocktake is optimised, by driving vehicles with attached cameras, scanning the surroundings while driving with sophisticated image recognition identifying barcodes to update the system. Retailer F explained how IoT enabled their manufacturers to evaluate machines, energy consumption, ambient conditions, status of inventory and the flow of materials via IoT technologies such as handheld devices, sensors and RFID. Retailer B also recalled a good demonstration of a "very systematic approach" by one of their manufacturers having sensors, tablets, smartphones, scanners and labels, which "makes them very reliable".

6.4.1.2 Interaction with suppliers

The role of IoT is important in strengthening communication with suppliers in ordering and other upstream exchanges, according to 8 retailers.

> "Some of our ready to serve food suppliers (e.g. Cakes, sandwiches) have provided us with an app that we can login and make orders. What we have to do is to select the product list, and the order will be automatically transmitted to the supplier. No need to call" [Retailer E].

Retailer B articulated that their buyers are using a handheld device when visiting supplier premises or product fairs to record supplier and product details to forward instantaneously to the company. Such devices are commonly used to streamline the procurement process.

6.4.1.3 Forecasting

Eight retailers discussed the role of IoT for extra data capture in forecasting to improve the planning and forecasting process in procurement and also at the supplier end. Retailer G stated that, in the planning process, they provide visibility to the supplier around 2 years in advance and that it is the IoT data that allows them to do that. Retailer F explained that the suppliers do get real-time visibility from point-of-sale (POS) data fed by various devices via an integrated system. Retailer D explained that IoT is a big part of this forecasting process and that most of the data is fed in real time from POS devices and handheld scanning kind of devices to this real-time analytics tool. That information is accessible anytime via smartphones and tablets. They have provided suppliers with access to their forecasting app, which automatically sends suppliers each week's fill rate report. The app makes the suppliers reply to them on that field rate report to tell what they haven't supplied and when they are going to be back in stock to help manage overall performance of supplies. They are currently looking at further integrating the supplier so that suppliers can provide real-time upgrades on shipments. In contrast, Retailer A stated that they are incapable of obtaining real-time updates for forecasting, but if they did, their manufacturer could streamline production scheduling with better efficiency.

6.4.1.4 Inbound delivery

The most common theme on upstream integration was the role of IoT to assist the primary inbound delivery process, which was mentioned by all 12 retailers. Everyone was consistent in how their transporters use GPS telemetry to find locations, track and trace vehicles, control fleets and optimise and consolidate routes. 3PL X corroborated that "we can provide a full track and trace portal with ETAs (estimated time of arrival) and updates on the whole way along the supply chain" and reinforced, "current route optimisation systems are very advanced with a lot of real-time streaming analytics to analyse traffic conditions to guide you through the most efficient way". 3PL X further went on to explain that not only are these technologies very helpful, they are also mandatory in some sectors such as pharmaceuticals where it is necessary to know where everything is all times and what conditions it has been in.

Some (7) retailers said the same about international delivery tracking.

> "Freight forwarder has RFID. When we have containers coming in from overseas we can track them. We would know who the shipping carrier is, who the container is loaded with and we would track. We have a portal to track" [Retailer L].

Three retailers and 3PL X spoke of cold chain monitoring.

> "We monitor temperatures from the supplier, throughout its journey to the DC. It's all Internet connected and monitored. During the travel if the temperature is off, we are going to get an alert. Probably that truck won't even reach us" [Retailer C].

Many other technologies were used in inbound delivery such as RFID to track container movement, barcoding, labelling and handhelds. Retailer B, in fact, explained the process and how different IoT forms are applied to the process.

> "When the product lands in Australia, our cartridge providers have handheld devices to know what containers being picked up, weights, VGM (Verified Gross Mass) and weather there is hazardous dangerous goods. When they pick it up or when it is at the cartage provides deport, we know straight away. We then plan the delivery. They have automated gages in their trucks to know the weights remotely. When they deliver it to our DC, geofence around the DC says it's arrived".

It was also explained by many that, currently, more drivers use devices for sign-on glass, instead of using paper run sheets, so that everything is transmitted in real-time. As Retailer G summarised, “there is many IoT technologies throughout, working together until we receive it”.

6.4.1.5 Receiving

Receiving was a theme discussed by 9 retailers. Out of these, 6 had IoT in receiving, 1 was in the process of implementation and 2 didn’t use IoT currently for this purpose.

> “At the supplies end, there would put the barcode on, the outer cutting barcode, when the products get here we scan that and we figure out this is the product, the outer cutting barcode is used at unit level as a unique barcode to identify pallets, boxes like that, it improves accuracy and productivity “ [Retailer C].

Retailer C explained how efficient they are in receiving due to the use an MDT (mobile data terminal) to clear 1500 pallets in 6 hours, at 24 pallets per hour per staff member. Retailer D also reinforced that IoT is the right direction for efficiency and prompt updates. Most managers discussed how IoT helps. Retailer L stated that their receiving inefficiency was due to lack of such systems.

6.4.1.6 Traceability

Upstream traceability was a theme discussed by 4 retailers. The 3PL X also confirmed that they always maintain a history of IoT data, in case of an incident.

Retailer C stated,

> “If the product is lost or withdrawn for some other reason as there is an allergen, with this technology, we can prove that we are not at fault …. Win can also be on having better traceability where the product is”

However, traceability beyond first-tier supplier was only discussed by Retailers A and I. While acknowledging the difficulty of tracking beyond first-tier supplier, Retailer A cited that,

> “Of having visibility on what's going on in those parts of the supply chain, without tools like IoT, it is very difficult to track”.

6.4.1.7 IoT-enabled supplier integration

All the respondents spoke very optimistically about the potential of IoT in supplier integration.

> “In terms of supplier interaction, I can see a big role buy IoT. There is more potential for upstream side of things” [Retailer C].

> "I definitely believe that these devices play a big role in bringing together us and our supplies. Better connection between us will only improve the activities" [Retailer E].

There were some instances of information sharing between partners, sharing forecasting information and operational level data, for example. Retailer B articulated that, to strengthen upstream IoT deployment, it is generally the suppliers and 3PLs who got to invest the most, and you can only get them to invest when long term partnerships and long-term agreements are agreed, and when the supplier was a part of the innovation and design program.

In summary, this section has demonstrated that there are many forms of IoT in upstream operations strengthening supplier integration, aimed at improving supply chain performance. The finding can be explained using organisational capability theory, where IoT as an aditional ICT capability potitively influencing the integration capability with the supplier (Huo 2012; Rai et al. 2006).

6.4.2 How IoT helps in internal integration

How the operational processes within the firm bounders are managed was subjective to each retailer, dependant on the company structure. All respondents except retailer K argued that IoT applications had a positive impact on their internal logistics processes.[5]

This section explains how various IoT forms in the Australian retail industry strengthen internal logistical integration. The major themes were around how IoT improves DC operations, retail store operations, HR operations and transportation.

6.4.2.1 Warehousing/DC operations/inventory management

The most commonly discussed issue was IoT's role in DC operational improvement, with only retailer E, F and K (who did not have in-house DCs) overlooking the theme. They all voiced positive outcomes from IoT deployment. For example, Retailer A explained how efficient picking has become with the use of handheld devices, when an order is forwarded providing an efficient picking order with product location, verifying the product after scanning and confirming the product has been picked. These handheld devices are very common in warehousing and DCs, benefiting many retailers (e.g. A, B, C, D, G, H, I, J) in receiving,

[5] Retailer K's opinion was, "Within our operation use of IoT is pretty minimum. The reason behind it is, we don't need to. Our operation model does not require such technology at this stage".

slotting, picking and dispatching and even in cross docking and splitting to zero. Retailer C spoke of a handheld device, which they call MDT (mobile data terminal), that helps them in barcoding and product identification, right from the receiving stage, through stocktake, up to replenishment. This outer cutting (closed standard) barcode is used at the unit level as a unique barcode to identify pallets. Boxes thus become redundant at the shop, replaced by inner cutting barcodes (open standard). However, their location picking is mainly done through voice pick, which is an Internet-connected voice recognition system. Retailer B further elaborated on voice pick, stating that it "is all about efficiency and productivity". Retailer B also spoke about their "latest cutting-edge sortation system", which labels cartons, gets scanned and goes to the location it needs to be moved to using RFID (only at the unit level on boxes and pallets) and the barcoding information.

The 3PL X described the amount of IoT technology they have put in place in warehousing for their retail clients. Some examples were scanners, some RFID but mainly barcode scanning, tablets on forklifts, mobile printers and a few conveyor control systems. It was further mentioned that there are a lot of smart-sensors positioned to reduce electricity usage, which is one of the highest expenses in warehousing.

Real-time data, reduction of inventory, productivity and process optimisation by increasing speed and efficiency and the reduction of human involvement and staff numbers were cited as the key outcomes of IoT in warehousing.

> "Office administrator used to enter the inventory data. When it goes into the system and by the time we find the errors, it will be about 2 days. But now it's just a matter of scanning the item and the system gets updated" [Retailer H].

Data accuracy due to minimised human intervention and human errors, improved safety due to reduced number of staffs on the floor and safety measures via technology were also mentioned. Security and surveillance, energy savings, convenience and fingerprint scanning for payroll purposes were some of the other themes within warehousing context. The majority (except Retailer G[6]) thought there was further potential to improve via IoT deployment. In terms of the further implementation of IoT in DCs, Retailer K discussed available technology in motion tracking, in terms of surveillance, to gather evidence on breaches of parameters and raise alerts.

[6] Retailer G who quoted, "Our warehousing operations is pretty good. Any IoT device that you can find out there, they would be using it. RFID is in use, handheld scanners, barcodes, temperature sensors, movement sensors, automation, robotics all are used for various is purposes".

Retailer H expressed that they were considering safety cameras with image recognition as a potential IoT deployment and image recognition technology that is capable of identifying inventory while driving to update the system by scanning goods, barcodes and everything around it. Retailer L, who identified that they had a very manual operation in their warehouse which drove inefficiencies, reflected that IoT would improve inventory management "exponentially", emphasising the need for a system that allows accurate real-time information,

> "There is a huge impact on the data not being accurate, due to delayed manual entry. We are always out of stock. But we continue to sell them online. It could be streamlined with bit of IoT" [Retailer L].

6.4.2.2 Instore operations

Except for Retailers A (no instore IoT) and L (e-tailer), the other 10 retailers discussed how IoT driven in-store technology can help their operations. The in-store technologies in use are, again, subjective to the nature of the business and the industry sector. Barcoding, POS (point of sale) devices and handheld devices of various kinds are very common forms of instore technology that were used by retailers.

Retailer B explained the ability of PDAs to remotely scan product barcodes, allowing staff to see the price and information of goods, prepare price change tickets and print labels instantly via a miniature Wi-Fi connected device. Retailer C discussed how the reports and orders are automatically generated via scanning of products during movement. Retailer I stated that self-checkouts have transformed their operation while 6 retailers spoke of the role of inter-networked POS barcode scanning devices. Retailers C, D, H and I have smartphone apps with autonomous reporting on sales, inventory, sales by state and where the targets are at, including plan-o-grams (a visual representations of each retail store's products) and alerts in real time, shared by cross-functional teams.

Retailers D and I spoke of the internet-driven barcoding technology. Retailer D detailed their need for outer cutting barcodes, "to be much faster in receipt of goods within the store". Retailer I explained how much individual item barcodes (closed standard) have helped them in their instore environment, especially in pricing perishables (e.g. meat, deli products) to make it fast and easy for them and their customers. Unique barcodes (closed standard) for perishable items are used by Retailer C as well. Retailer G stated that they are currently barcode driven, but their global team is contemplating moving in the direction of RFID soon to improve the accuracy of data communication and service levels.

Handheld devices are employed in retail stores for multiplicity of purposes. Four retailers explicitly mentioned the use of handhelds in stock takes.

> "RF guns are multitasking, can take photos and send, panic buttons, all that" [Retailer J].

Retailer J, in fuel retail, spoke of a unique IoT application. Their underground fuel tanks have sensors fixed to track the stock levels. The sensors automatically feed to the computer in the store, as well as the central operations at the head office to monitor fuel availability. It will send alerts if there is an unusual event such as theft. If the fuel level goes below 5%, the site is shut down because the dirt concentration can be high, and it can clog the pumps. When the fuel level falls below 30%, the order needs to be dispatched remotely. The system calculates when the next fuel trip is needed, analysing past data, and despatches the stock.

Retailer J articulated,

> "Now the system has taken the responsibility, I'm not fussed even if the stock goes low. I'm very confident that the delivery will get there before we run out of stock".

The manager further reiterated that the price of the fuel on pumps and the pricing display screens are remotely controlled by the pricing department. Even their printer cartridges are monitored offsite and replenished automatically.

Retailer E believed that IoT had revolutionised the restaurant industry, for example by using iPads to take orders.

> "Rather than the previous system where you write down the order in a piece of paper, tell everyone about the order and then enter into the system, here when you enter the order to the iPad, everything gets updated. It is very convenient".

The restaurant owner further went on to explain their reconciliation system, where they register the stock coming in using their app which analyses supplies and the day's sales to calculate the stock on hand and even P&L (profit and loss) for the day. They have a fridge that is Internet connected so that the temperature can be monitored and controlled remotely. The remotely monitored temperature conditions of refrigerators is also practiced by Retailers C and I as well.

Retailer G has people counters to count the number of people who come in and out, and "sale through information" which analyses who is buying what using demographic facial recognition, both are monitored and analysed by the head offices in real-time. Retailers G, K and J had motion tracking as surveillance. All other retailers use much simpler remote video surveillance.

> "We have a camera system connected to the Internet so that we can monitor what's going on in the restaurant anytime anywhere through my phone. Staff members are

aware that we are watching so they will be nice to the customers, be more efficient and not slack. It reduces theft as well" [Retailer E].

Retailer E has the cash register connected as well, to remotely monitor the progress of sales, providing them with the ability to compare data with surveillance video to ensure that staff are entering sales correctly.

The improvement of accuracy in inventory, real-time information for ordering and planning, reduced instore inventory, efficiency improvement, productivity, labour saving and reduced human intervention are the key rewards of having IoT as an instore technology.

Retailer J mentioned that the monthly promotions, currently produced on printed material, will soon be changed to display screens that can be controlled by the head office, and in time price changes of products will be carried out remotely by head office too.

Retailer H stated that,

> "Image recognition is progressing in a big way due to IoT. The same technology is looked at in retail shops to look at the shelf availability, see if they are empty or how much stock that there is. Everyone thought RFID will do all that, but now they are looking at alternatives".

6.4.2.3 IoT for identification – Human Resource application

Utilisation of IoT devices for identification, tracking, payroll and access control is discussed as a growing trend by many interviewed; 7 managers spoke on this theme. 4 of them employ FOBs (keyless entry devices) for accessing different areas. Retailer L and 3PL X spoke of having fingerprint scanners connected to payroll systems. Retailer K (in the security and surveillance technology trade) stated that they use facial recognition (one of their own products) for access control.

> "Facial recognition is nowadays commonly used as means of identifying a person, to get into a building for an example, you don't need a key as such" [Retailer K].

Retailer K explained that the advantage of such applications is that they can digitally identify, record, monitor, track and trace each register entry in a central database and centrally update new identities for all scanners simultaneously.

6.4.2.4 In-house transportation

Interestingly only 3 retailers (B, C, D) mentioned secondary inbound logistics operations (the movement of goods from the DC to retail stores). However, all spoke positively of the role of IoT in this space.

> "We use IoT in a complex system, in our trucks for planning and safety purposes. We are tracking to verify, are they taking the designated route, are they within the speed limit and the idling time" [Retailer C].

6.4.2.5 IoT-enabled internal integration

Out of 12, 11 retailers articulated that IoT has improved or has the potential to improve their in-house operations by facilitating their internal process integration.[7]

> "What we want to see as managers is the numbers. Bringing these technologies has streamlined our internal operation. It's very efficient now in comparison, reducing data entry errors and the report generation are instant." [Retailer H].

Some spoke of how IoT has improved in-house cross-functional communication,

> "Everyone looks on our smartphone app to monitor our sales. That's being really helpful for communicating performance of our stores to everyone in the business" [Retailer D].

> "The bigger benefit would be communication, shared understanding and everyone being on the same page" [Retailer L].

Retailer F expressed how IoT can help improve customer service via stock availability, so they can "focus more on providing customer service than worrying about inventory". Retailer L pointed out that going paperless would improve the operation via automatically updates and better integration with online systems.

In summary, this section has demonstrated the existence and the potential of IoT in in-house business processes to improve DC operations, store operations, HR operations and transportation strengthen internal integration for greater supply chain performance. The organisational capability theory explains the relationship where IoT as an aditional ICT capability improving integration capability internal to the firm (Huo 2012; Rai et al. 2006).

6.4.3 How IoT helps in customer integration processes

The customer interaction process was very subjective to company structures and, more specifically, the retail sector, form and the nature of business. Thus, the intensity and the methods of IoT deployment were heterogenous too. Retailers in general saw IoT as an

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[7] Despite Retailer K expressing that IoT is not required in their in-house processes, they said that the IT manager is a strong advocate of IoT within this space.

application for them to connect with their customers and improve their services, with a lot of optimism about the future potential.

> "In retail, we interact directly with the consumer. If we can get the right data and communicate effectively that in terms convert into better service levels for the customer" [Retailer G].

The customer integration space seems to be well benefited by IoT disruption.

> "It was a good progression as a lot of new applications coming in, especially when it comes to the customer side applications" [Retailer E].

The various ways in which IoT helps in downstream integration is discussed below. The major themes were around in-store operations, understanding customers, promotions, improving the online presence, picking and despatch, deliveries and receiving and improving ratings.

6.4.3.1 Instore technology to help brick and mortar customers

Except e-tailer L, all other retailers expressed that IoT instore applications helped in customer interactions. How the barcoding and POS (point of sale) devices unite to improve speed and convenience for customers was discussed by 9 retailers. Retailer I revealed that self-checkouts have made it fast and convenient for the customer and has offered an alternative.

> "You can see how many people choose to do self-checkout rather than going to the checkout staff" [Retailer I].

Retailers C and I explained that individual item barcodes on perishable products make the check-outs for customers more convenient. Five retailers mentioned that item level RFID would be handy.

> "RFID can reduce the checkout time by so much. Customers don't like waiting" [Retailer J].

Retailer J further mentioned about a self-checkout phone app that is piloted at present where,

> "You take your stuff, scan them and put them in the basket and walk out".[8]

Out of stock status is a great concern as 31% of consumers will buy from elsewhere and 26% will buy a different brand in this scenario (Satapathy et al. 2015). Product availability due to real-time data, leading to fewer lost sales and customer retention was a theme discussed by 6 retailers.

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[8] At the time of writing, Amazon launched its Amazon Go concept store to the public, with no cashiers, no lines, no registers, with IoT being an integral enabler (AAP 2018).

> “When they don't get to open up the shiny new phone, they are disappointed. It is called "unbox therapy". We can't have products unavailable” [Retailer F].

How digital payment methods have reduced hard currency circulation is the next important theme discussed by 7 retailers. Retailers spoke of the role of wired EFTPOS machines to bring digital currency into the market and now the wireless version making it even more convenient.

> “EFTPOS machine at the store for an example is progressively providing a seamless service” [Retailer G].

Some spoke of evolving options from a magnetic strip in bank cards to pay-wave via an electronic chip (tap and go options via NFC [near field communication]), while others spoke of payment via mobile phones such as Apple Pay and smartwatches. Retailer J described an app recently introduced by a competitor that enables the customer to pay for the fuel at the pump without going inside the store. Retailer C and I spoke of a form of IoT-based image recognition technology currently used in their car parks to identify vehicles that exceed the parking limit, so that their customers have parking availability data.

However, customer applications such as in-store guidance for shoppers cited in the literature (Porkodi & Bhuvaneswari 2014; Sundmaeker et al. 2010) was not mentioned in any dialogue.

6.4.3.2 Understanding customer needs

Understanding customer needs via a variety of in-depth data captured by IoT devices is a theme discussed by 7 retailers. Combining POS data with reward cards to analyse the demographics of the customer was brought up by many. However, Retailer G’s system seems to be very advanced, where it captures video data of people walking into the stores to identify their age and identify who buys what via the POS systems. People counters analyse this data together to identify customer needs and conduct thorough forecasting. Retailer K confirmed that many retailers have purchased such systems like the above reported from them to better analyse customers.

> “IoT can give us lots of data on customers. More data about customers, better decisions we can have in the future” [Retailer E].

6.4.4.3 IoT as a promotional tool

Eight retailers spoke of exploiting IoT, 4 specifically on smartphones, as a medium to reach customers by helping to find retailers and promote products.

> “IoT definitely helps us reach the customer, given everyone is on smartphones now and having access to Internet 24/7” [Retailer L].

Another key theme discussed by 6 retailers is IoT location awareness, specifically on smartphones, helping to find nearest or specific store locations and providing GPS directions to get there. Retailer J spoke of a promotion of a different kind, which is an app that encourages price matching, by checking the fuel prices around the area. Retailer D use their app to track loyalty points and for marketing. Retailer G revealed that they use IoT-based facial recognition to demographically customise in-store advertisements of their products. Retailer K explained the scenario and confirmed that they themselves have installed facial recognition to influence customer behaviour in retail environments.

6.4.4.4 Online presence and digital order making

The way customers find products and place orders is another key sphere effected by IoT application, as noted by 6 retailers.

> "Our B2C platform allows customers purchase the products online using either that computer or the smartphone or the tablet" [Retailer A].

Retailers A, D, E, G, H and L spoke of how having a pervasive device in customer hands has positively affected their sales. Some had apps, while others had websites accessible via pervasive devices.

> "Having that connection of Internet node in your pocket has affected immensely on online sales" [Retailer G].

The restaurant industry is intensely disrupted by IoT, as expressed by Retailer E, especially owing to self-ordering. In-store, they provided iPads for customer to make orders, improving sales. The retailer believes that customers order more when they can order themselves anytime. The restaurant also has their own smartphone application, through which the customers can pre-order remotely.

> "Office workers can't wait for the order to be ready, so it saves time" [Retailer E].

Four retailers highlighted the prevalence of third party apps which take customer orders, processes payments and manages the delivery (4PL model). UberEATS is a brand that emerged frequently as an affirmative example.

> "We are with UberEATS. Since we signed up with them, we have increased our sales by so much. They pick up and deliver, too easy" [Retailer E].

6.4.4.5 Picking and despatch

When an online order has been received, how IoT ensures accurate and timely picking to enable speedy despatch is a theme discussed by 4 retailers who run online operations. Retailer A expressed that customers primary objective is to receive their order on time in full, thus the technology to support this is necessary. Retailer H explained how IoT handheld devices help them to ensure timely, accurate despatch and notify customers of progress. Retailer D stated that their biggest challenge was that their despatch was not efficient enough, thus negatively affecting their online sales. However, with their current system using various IoT technologies, they have been able to improve the process so that when the customer places an order, the system initiates a dynamic process to find the store closest to them, where the stock is going to be best available, closest to the delivery route and with cheapest freight rate, and then their handheld devices help store staff pick the order quickly and notify deliverers to pick up.

6.4.4.6 Deliveries

Eight retailers affirmed that IoT helps their customer order delivery processes. All of them had their delivery operations outsourced.

Retailer D explained how their delivery tracking process,

> "The couriers track the delivery from our door step right to the customer, so the customer and us both can track via a portal. There will be progressive updates to customers. We will get an alert as soon as the order gets delivered. The notifications are so fast, when the order is passed from the handheld all the emails are sent including to the customer saying your delivery has arrived".

Out of these, 6 retailers discussed visibility as a key benefit which IoT provides to the customer. Retailer E asserted that with UberEATS the customer can track the delivery all times, and "the customers love it" as it is much more convenient.

> "Overall, I would think that it improves the customer service levels, as we are able to see in real-time what is happening with the package" [Retailer K].

Six retailers spoke of automated alerts along the way at key benefits for the customer.

> "Back in the day if you order an item from overseas or even from Australia you have no idea until it arrives at your doorstep. But now you can track and be alerted all the way" [Retailer H].

Providing good route options to couriers is another key feature discussed by 4 retailers. Shorter, better optimised routes, retrieving optimised destination sequences, avoiding traffic, order consolidation and efficiency were some advantages discussed within this theme. 3PL X also described many technologies used in delivery. Retailer F explained that delivery is an area they can improve with IoT, as, not having that integration and visibility, they currently have no idea how and if the customer is being served until the supplier manually enters it to their system.

6.4.4.7 IoT's role in a rating-based economy

Customer evaluations help consumers make decisions as more credible and trustworthy sources than brands themselves (Maslowska, Malthouse & Bernritter 2017). Five retailers spoke on the theme of IoT as a tool to receive (or improve) customer ratings.

> "The best thing of this pervasive computing is ratings and reviews. So, we have provided a platform for people to rate and review our items" [Retailer H].

Retailer E also explained that their industry is very much review-based and so, when a customer visits a restaurant, the search engines picks up their location through their smartphone and requests that they rate the place. Furthermore, when a delivery is made via UberEATS, the restaurant, the product and the driver get rated via the app, which adds pressure on the entire supply chain. What all retailers stressed is that smartphone presence has increased the extent of ratings, and that IoT is central tool to improve their ratings and to respond to customer inquiries and comments.

> "IoT is so important now as there is lot of urgencies to get the house in order, to respond to consumers. They can publicly advocate without any fear of retribution. Their avenues of doing that are immediate and far reaching" [Retailer I].

6.4.4.8 IoT-enabled customer integration

Despite having heterogenous operations for downstream operations, one theme that was very consistent was how much IoT systems play a key role in customer satisfaction. 3PL X also confirmed, "In terms of serving the customers' customer, IoT does really help serve them better". It constantly came up that the launch of the global e-tail giant "Amazon" has made local retailers worried and intimidated by Amazon's costly technology and ability to serve the customer. It is also very apparent that vertical competition between firms and different forms is making retailers resort to such technology as IoT to counter competition.

The four key spheres that retailers rely on IoT are understanding customer needs, promotions and suggestions, improving customer service, and encouraging reviews and improving their customers ratings. Some thoughts retailers shared when it comes to how IoT in customers integration include that customers are "getting smarter" [Retailer H], "well informed" [Retailer B], "very concerned of how the products are made and what goes in to what they eat" [Retailer I], "concerned of reviews" [Retailer H], "brutal in ratings" [Retailer I], "customers are getting lazier and lazier" [Retailer E] and "people shy" [Retailer I]. Incidentally, young consumers' drive and hunger for IoT utilisation was also a distinct theme.

In summary, this section discusses IoT applications in customer related business processes to help retailers in in-store operations, understanding customers, promotions, online presence, picking and despatch, deliveries and ratings to argue for IoT positive role in customer integration to effect supply chain performance. The organisational capability theory is grounded on this relationship where IoT providing additional ICT capability to furthur improve integration with the customer (Huo 2012; Rai et al. 2006).

6.4.5 How IoT-enabled internal integration effect external integration

Ten retailers discussed this relationship. Most expressed that, being the dominant party and being closer to the customer in the supply chain, they can influence IoT integration. Some thought that external parties had influenced them, while others observed that influence works both ways.

6.4.5.1 Ability to influence IoT-enabled supplier integration

As the dominant partner in the relationship (Wang, Tang & Zhao 2017), 10 managers expressed that they are able to influence their upstream partners to comply with IoT strategies.

> "From our perspective, I would say we are able to influence our suppliers to implement IoT in the supply chain operations so that we can get visibility. Being Retailer, we have some sort of power to influence them" [Retailer F].

The 3PL X also confirmed that they implement a lot of IoT technologies to fulfil customer (retailer) demand. Retailer C rationalised their influence on partners as "we are trying to work together to maximise the productivity".

6.4.5.2 External influence in IoT-enabled supplier integration

In contrast, 4 managers (C, G, E and H) spoke of instances in which they were stimulated by upstream suppliers and transporters for IoT-enabled upstream integration.

> "Sometimes it is the supplies systems that we are using so that it is the supplier who sets the standard" [Retailer E].

6.4.5.3 How IoT deployment influences external partner selection

IoT related technology application influences external partner selection, as noted by 7 retailers and corroborated by the 3PL X.

"When selecting suppliers, what kind of transparency they can give (sic). Same with transporters. It is a prerequisite to have these technologies" [Retailer H].

Retailers A and I expressed that they would expect suppliers that have such technology to provide them with transparency beyond first-tier suppliers. Retailers A and L, who both confessed to not having very good internal IoT systems, expressed that they look for external partners, especially 3PLs, to "piggy back" on their technologies.

6.4.5.4 Ability to influence IoT-enabled customer integration

Having immediate contact with customers, retailers can have a robust influence on them (Porter 1974). Accordingly, 8 retailers spoke on how they can influence downstream IoT integration. Five retailers spoke of getting customers more connected via smartphone apps as a way of influencing them.

"Given that we are directly dealing with customers, we can always encourage them to be more integrated with smartphones" [Retailer F].

Retailer G spoke of creating communities with various apps. Retailer D explained how they encourage customers to be more integrated via a loyalty program as a perk to use their app. Retailer H also stated that they sometimes have online promotions to encourage customers to download their app and encourage app installation when customers visit their shop.

Having delivery partners that can integrate them with customers via track and trace portals, was discussed by 5 retailers.

"Most customers like checking tracking portals. We can be more connected that way" [Retailer A].

6.4.5.5 External influence on IoT-enabled customer integration

Four retailers expressed circumstances where customer influence has driven them into IoT technology to be more connected with their customers. Retailers A, H, and L stated that the key reason they have been driven to track and trace portals was customer expectation. Retailer E explained that the reasons that they had signed up with UberEATS and other such platforms were firstly because it was an opportunity to integrate with a wider customer base and secondly because of customer expectations of greater connectivity throughout the process.

6.4.5.6 The effect of IoT-enabled internal integration on external integration

In summary, the findings suggest that there is a positive link between IoT-enabled internal integration and external integration. Overall, it can be determined that IoT-enabled internal integration effects external integration. Simultaneously, external parties also influencing both supplier and customer integration. As explained by organisational capability theory, strengthened internal integrative capabilities via IoT can be a foundation to develop external integrative capabilities (Huo 2012). However, no retailer articulated that having implemented IoT for external integration had any influence on their IoT efforts for internal integration.

6.4.6 Additional capabilities of IoT in supply chains

There are various additional capabilities that IoT deployment has passed on to supply chain operations. The key themes were (real-time) visibility, auto-capture, intelligence and improved communication. It is evident that these additional capabilities are what facilitates IoT to perform beyond generic ICT in supply chain operations.

> "Benefits of electronic information is obviously the key thing " [3Pl X].

6.4.6.1 Visibility

Improved visibility is the key operational value of IoT deployment, identified by 10 retailers and the 3PL X.

> "I think at the end of the day, supply chain is all about connecting the dots. I think what IoT does give is visibility" [Retailer A].

It is evident that IoT's ability to be omnipresent in the supply chain is a key factor for this improved visibility. Retailer G further reinforced the value of visibility when trying to balance demand and supply, and clarified that having visibility of where the product is and when it is arriving helps and "it's all about having the right data and having that visibility".

Importantly, 6 managers specifically spoke of IoT as an enabler for *real-time* visibility.

> "Everyone is looking at getting real-time information into the system. That's why IoT is so important for us" [Retailer H].

Seven retailers referred to real-time visibility in inventory management.

> "IoT is streamlining it (DC) live right now" [Retailer H].
>
> "We have been able to get more information, more visibility of information and make better decisions based on the information. Which has helped our flow of stocks and reduced our stock levels" [Retailer B].

6.4.6. 2 Auto-capture and human resource implications

Seven retailers highlighted how IoT auto-capture data to reduce the role of the labour or assist labour.

> "The customers making own orders (self-order) by tablets helped reduce waitering staff by almost half, as we only have to serve the order" [Retailer E].
>
> "You take it, scan it and pass it on. That's all it's doing. Before it used to be, you take it, fill a form, then you despatch it, and someone else will need to process it (do data entry) again". [Retailer H]

6.4.6.3 Supply chain intelligence

Ten managers confirmed that supply chain intelligence (see 6.3.11 Data capture and analysis) is a benefit of additional data capture by IoT. The intelligence derived from analysis outcomes was considered to be one of the key aspects of supply chain performance. Five managers thus spoke positively of real-time streaming analytics as a novel addition to IoT platform, and how this real-time intelligence can further improve supply chain performance.

6.4.6.4 Improved communication and supply chain relationships

Six retailers declared that having IoT devices in their supply chain has improved communication between supply chain partners.

> "IoT is enabling us to communicate better with 3PLs, customers or supplies" [Retailer C].
>
> "Whole thing is geared towards brand integrity, credibility and brand trust, and integration of these kinds of technologies allow the brand owner or Retailer to respond in real-time to media, to customers, to consumers, to investors, all these external stakeholders" [Retailer I].

Four retailers specifically mentioned that IoT as a communication tool (i.e. mobile phone apps, vehicle tracking technology) can improve supply chain relationships via better interaction between supply chain entities.

> "I think that there would be a better relationship between internal and external stakeholders if IoT is developed, because it will improve the line of communication better, improve collaboration and build up trust, because of the transparency is provides" [Retailer C].

6.4.6.5 IoT-capability in SCI

In summary, (real-time) visibility, auto-capture, intelligence and communication are found to be IoT capability that have emerged in addition to legacy ICT capabilities in strengthening SCI, to further improve supply chain performance. IoT promises real-time track and trace of material in an interconnected network (Van Breedam 2016). Its pervasive auto-capture capability reduces human intervention (Borgia 2014) by reducing the dependency on human-entered data (Ashton 2011). Sensing predefined events in supply chains being the first-step for information sharing, IoT enhances situational awareness and avoid information delay and distortion for greater collaboration (Lee & Lee 2015).

6.4.7 How IoT- enabled SCI effect supply chain performance

All 12 retailers and the 3PL X were positive about the effect of IoT integration in improving supply chain performance. The discussion was not limited to the traditional supply chain performance dimensions of cost, quality, delivery, flexibility (Gunasekaran et al. 2004), but also included both sub-dimensions of each and additional elements.

6.4.7.1 Cost reduction

Cost reduction is a key supply chain performance dynamic identified by all managers except retailer I.[9]

> "Using IoT can definitely reduce the overall supply chain cost, for sure. I can see from my end it can reduce the cost of the suppliers, their delivery cost and also our operational cost" [Retailer E].

Cost savings were reported in terms of efficiency, optimisation, energy saving and wastage as the key themes. Ten managers spoke of efficiency improvement as the catalyst for this cost reduction. Relatedly, productivity improvement was cited by 9 retailers. Similarly, 8 retailers observed optimisation of their supply chain processes.

Six managers thought energy savings (i.e. fuel, electricity) can reduce cost.

> "This optimisation can save both electricity cost in warehouses and fuel cost in transport" [Retailer H].

The 3PL X noted that IoT solutions reduce fuel consumption and electricity in logistics.

The theme of time saving in conducting tasks was brought up by 7 retailers.

> "If the customer could log into a portal, even just to track and trace, that saves them picking up the phone call, calling, having a 20-minute conversation" [Retailer A].
>
> "You can update all your machines centrally. No need to run to each gadget" [Retailer K].

[9] Retailer I, who claims to look at the supply chains through the "sustainability lens", interestingly overlooked cost.

The reduction of inventory levels as a way of reducing cost was discussed by 5 retailers.

> "You can implement just-in-time very well, if you use IoT properly. Effort should be on reducing the inventory holding cost near zero" [Retailer J].

Finally, the theme of reduction of wastage was mentioned by 5 retailers.

> "From waste point of view, I guess greater transparency and accuracy over stock would stop wastage, that could potentially be more sustainable" [Retailer L].

Consolidation of loads was discussed by 2 retailers and confirmed by 3PL X as well.

Reduction of lost deliveries, thus claims, was mentioned by two retailers. Reduction of theft due to surveillance and RFID tagging and decreasing returns was also mentioned.

6.4.7.2 Quality improvement

Object virtualisation can be utilised to ensure various quality conditions in supply chain management (Verdouw et al. 2016). Parenthetically, all 13 managers interviewed cited quality improvement, but in different ways.

> "It (IoT) can improve the quality standards of the whole operation" [Retailer E].

Improvements in service quality was a key theme discussed by 9 retailers and the 3PL X.

> "From the service quality point of view, that's probably the big thing" [3PL X].

Retailer E explained how important it is to maintain service standards in the restaurant industry and stated, "IoT is the new thing to improve service standards in restaurant industry".

Eight retailers and the 3PL X spoke of the effect of IoT to improve or sustain their product quality. However, the opinion on the effect of IoT on their product quality was split, depending on the industry. While 3 retailers thought that IoT has no potential to affect the quality of their product, 5 retailers spoke positively.

> "Food safety is a huge thing. If we have any issues in quality, we would be able to know in advance. We can investigate the history" [Retailer C].

Another frequent theme was the improved accuracy of their supply chain functions, supported by 7 retailers and corroborated by the 3PL X.

> "It is mainly the accuracy, less mistakes" [Retailer H].

3PL X also noted that "one aspect that has improved is accuracy of deliveries, accuracy of documentation, accuracy of processes".

Retailer L complained about not having such a mechanism,

> "There is a huge impact on the data not being accurate. So, we are always out of stock. It affects everything".

Another aspect that was complemented by IoT is convenience. This was revealed by 6 retailers. Retailer I spoke of the potential of IoT in their operation,

> "It would make things easy for our staff, probably less stressful as well, because there will not be any data entry".

Finally, 5 managers cited safety improvement.

> "We use a lot of IoT technology to keep people safe. By saying that it's more about identifying behaviour, addressing that, coaching driver's, coaching people so they can be safe at work" [3PL X].

6.4.7.3 Delivery standard

10 managers including 3PL X pointed to delivery standards as a key sphere in which IoT has, and potentially can further, enhanced their supply chain performance.

> "I think the very end customer will benefit by faster deliveries, or better service, that's the expectation. We are accountable to our customer (retailer) and our customers' customer" [3PL X].

Retailer B and L spoke about the negative effect on deliveries when IoT is not available,

> "I guess delivery quality in regard to the integration potentially, that's a kind of a gap in our supply chain" [Retailer L].

5 managers exclusively mentioned delivery speed. Correspondingly, 4 managers spoke of timely deliveries.

> "We want to be just-in-time, this is the technology to help us" [Retailer C]".

The 3PL X also confirmed that getting information on time improves their responsiveness.

6.4.7.4 Added flexibility

Nine retailers and the 3PL X cited having IoT positively affecting the flexibility of their operations.

> "It does improve flexibility, mainly because you get everything live, so you have time to do different things" [Retailer H].
>
> "I think flexibility comes all around when information is around". [3PL X]

6.4.7.5 Customer relationship management

The effect of IoT on customer relationships was a theme discussed by 8 retailers.

> "With this new (IoT) system, there is less complains and more satisfied customers" [Retailer E].

Echoing Retailer E, Retailer L explained that not being able to fulfil orders due to lack of transparency has resulted in many unsatisfied customers.

6.4.7.6 IoT-enabled SCI and supply chain performance

The findings suggest that embedding these pervasive IoT devices to support legacy ICT in supply chain processes improves SCI and has an impact on the traditional operational performance dynamics of cost, quality, delivery, flexibility and improved customer service. As explained by organisational capability theory, IoT seem to furthur improve preformance via its positive effect on SCI (Huo 2012; Rai et al. 2006).

The literature suggests that supply chain performance is likely to be significantly affected by the evolution of IoT (Dweekat & Park 2016). IoT can decrease supply chain costs by facilitating real-time optimisation of business processes (Dweekat & Park 2016). Speed of delivery and delivery reliability, from product design to the end consumers, is an outcome of the real-time information provided by IoT technology (Mishra et al. 2016).

6.4.8 How IoT-enabled supply chain performance effect firm sustainable performance

Interviews suggest that IoT deployment in supply chains can improve firm performance.

> "Of course, there is a long way to go with this technology, but IoT can not only help organisations to be more financially viable but also help them be more socially and environmentally responsible as well" [Retailer I].

Even though some were very direct on the IoT's effect on triple bottom lines, mostly, the performance aspects were subjective to the nature of the firm.

6.4.8.1 Economic sustainability

All 12 retailers and the 3PL X discussed economic sustainability due to IoT deployment.

> "Definitely, hundred percent, there is a financial gain in using these technologies" [Retailer E].

3PL X warned,

> "Sometimes, it's hard to put sales growth and cost reduction down to technology alone", then articulated, "But us having this technology help our customers in their economic growth, mainly because, by increasing the service and decreasing the cost you charge them, you give them an opportunity to increase their profitability".

Economic sustainability is addressed under the themes of growth, cost reduction, return on investments and competitive edge.

6.4.8.1.1 Growth

Twelve managers spoke about company growth potential due to IoT deployment in their supply chain. Nine addressed the theme of sales growth.

> "It helps in sales growth, because it improves service levels" [Retailer F].
>
> "It has improved the customer base, for example UberEATS, a segment we usually don't get" [Retailer E].

Retailers G and K stated that their facial recognition tools identifying customer demography to tailor advertisement displays are a great sales and promotions strategy.

Enhanced customer satisfaction was mentioned by 7 retailers. Five retailers spoke of consumer trust.

> "When you show customers that you are up to date with such technology, they start trusting us more" [Retailer E].

Retailer I explained that integration of technologies such as IoT and blockchain [10] can improve brand integrity, credibility and brand trust. Lost sales reduction was discussed by 6 retailers. Relatedly, customer retention was another theme discussed by 5 retailers.

> "If we can't have products available and send it at a shorter lead time, there will be no customer retention or growth. That's why we have IoT" [Retailer H].

IoT as a tool to augment brand reputation or protect it was discussed by 5 managers.

> "Having leading technologies such as tailor-made advertisements kind of help our brand reputation" [Retailer G].

Both Retailers A and I spoke of traceability of the upstream supply chain with the help of IoT to safeguard brand reputation. Recruitment of good employees because of technology deployment was another appealing theme discussed by 3 retailers.

Retailers G and H both stated that their organisations being leaders in introducing latest disruptive technologies attracted good staff. Retailer I, while agreeing with the above, quoted,

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[10] The open source blockchain technology offer functionalities beyond current legacy technologies, in addition it offers data security and cost-effective transmission of transactions in peer-to-peer networks, without a central system. Thus blockchain technology can be employed as a platform for micro level IoT integration (Korpela et al. 2017).

> "Young people coming into the workforce are looking for real drivers of brand integrity. They want to work for an organisation which they feel aligns to their values" [Retailer I].

6.4.8.1.2 Cost reduction

Overall, 10 managers spoke of cost reduction for the overall firm as a result of IoT deployment to help conduct their supply chain activities. Out of these, 8 retailers and 3PL X confronted cost reduction directly. It shows evidence that the cost reduction in supply chains has passed onto the focal firm itself. Relatedly, four retailers spoke of their productivity improvements within the firm.

> "It's (IoT) improved productivity immensely. We look at cost of sales, percentage has improved" [Retailer B].

3 spoke of their ability to reduce staff numbers due to productivity improvements by IoT.
7 retailers directly stated that 3PLs could reduce the cost of their services to retailers, due to their widespread use of various IoT applications to optimise operations.

> "A reason that 3PLs can give us such low prices is that they employ these technologies for efficiency" [Retailer C].

6.4.8.1.3 Return of investment

4 managers spoke on the theme of company return on investment.

> "Even a minor change by IoT within the business can have a huge impact on return of investment" [Retailer A].

Relatedly, Retailer J articulated the optimisation of resources.

> "If you use this technology correctly. You can run with a reduced capital cost. For example, extra stock that is blocked in here can be better utilised".

6.4.8.1.4 Competitive edge

IoT can help enhance the competitiveness of global corporations (Del Giudice 2016), a theme discussed by 4 retailers.

> "We assume, we find information faster than others. It obviously gives us the edge from our competitors. It's all about who takes the next move first" [Retailer H].

6.4.8.2 Environmental sustainability

All 13 managers believed that IoT deployment in their supply chain processes could help their firm become more environmentally sustainable.

> "In terms of environment, it does make it more sustainable. I think IoT is a big part of us to be an environmentally sustainable company" [Retailer G].

3PL X brought up the chain of responsibility,

> "At the end of the day, they (retailers) are the ones creating the carbon footprint, even though we are moving it. We are just the service provider".

Likewise, most retailers expressed their responsibility for the outcomes of their 3PLs.

> "We always look at the environmental impact of our 3PLs as a chain of responsibility" [Retailer l].

The ways in which IoT impacts retailers' environmental sustainability spectrums were diverse and discussed under the themes of reducing paper, reducing carbon footprints, energy saving and minimising wastage.

6.4.8.2.1 Paperless operation

Digital platforms stimulate paperless functioning, thus saving environmental impacts (Mphidi & Snyman 2004). Interestingly, decreasing the use of paper is the most frequent theme, cited by 8 retailers and the 3PL X.

> "More drivers using devices for sign on glass, instead of using paper" [3PL X].
>
> "Bin cards and manually entering information is past" [Retailer D].

6.4.8.2.2 Reducing the carbon footprint

Vehicle emissions are a cause of inflated carbon footprints (Elhedhli & Merrick 2012). Reduction of emissions is the next popular theme, discussed by 6 managers.

> "Obvious is optimisation, route optimisation, operational optimisation. All that has reduced carbon footprints in the supply chain" [Retailer H].
>
> "We are able to take a lot of data form engine management systems, to analyse fuel efficiency. So now we can start comparing that between trucks and identify drivers that don't drive economically. Just like high revving, sort of stuff. Another one you can tell is when drivers are idling. Idling is a huge problem in the industry. Drivers turn the truck on, wait for 15 minutes and drive off. We are getting lot of reporting now, so can we try and reduce that whole idling time. From an emissions point of view, IoT is a big thing for us" [3PL X].

6.4.8.2.3 Energy saving

Electricity saving is another key theme mentioned by 6 managers. The causes were disparate. Most spoke of warehousing.

> "It's all sensor and motion technology in warehouse, all Internet connected system, to make it a smart building" [Retailer C].

> "When the turnaround time is less, the energy needed for that order is less. It has reduced the requirement of the space also which means less energy" [Retailer H].

The 3PL X also expressed that there is a lot of IoT technology in their logistics to try and reduce electricity consumption.

6.4.7.2.4 Minimising wastage

Three retailers mentioned minimising of wastage as an effect of IoT. Greater transparency and accuracy seem to reduce wastage. Also, previously un-trackable products having been able to track apparently reduces the number of goods left unheeded in the warehouse.

> "From waste point of view, I guess greater transparency and accuracy over stock would stop wasting, that could potentially more sustainable" [Retailer A].

6.4.7.2.5 Returns and recycling

In terms of reverse supply chains, discussion was sparse. Retailer J mentioned that the returns can be reduced due to visibility. The 3PL X felt that, "In terms of recycling and returns in retail, IoT helps in a big way". However, no other interviewee touched this theme, despite scholars claim that potentially IoT has a big role in return and recycling (Kiritsis 2011).

6.4.8.3 Social sustainability

IoT application can be used socially smart to enhancement of quality of life (Asghar et al. 2015). Twelve managers spoke about the social sustainability theme.

> "In terms of social aspect, I think IoT has done lots, potential is more" [Retailer F].

However, perceptions of how IoT can improve social sustainability vastly differed and ranged from themes of safety to job satisfaction.

6.4.8.3.1 Safety

Safety was the key theme raised by 7 managers.

> "Sensors and other safety devices are in place. It definitely improves safety, especially in a warehousing or supplier factory environment" [Retailer G].

Retailer B explained that IoT devices help them better manage hazardous goods,

> “Information of dangerous goods and hazardous material are there, compliant to legislations. They can be accessed by handheld devices at any point by scanning. That improves the staff safety”.

3PL X stated that “road safety is huge” and the “use of IoT can definitely make them better drivers, and it removes the unsafe drivers”.

6.4.8.3.2 Job satisfaction

Improvement in job satisfaction due to IoT deployment is a theme discussed by 5 retailers. However, the explanations were varied. Four retailers spoke of ease of use.

> “It would make things easy for our staff. Probably less stressful as well, because there will not be any data entry” [Retailer L].

Retailers H and I mentioned that having such technologies create a pride among staff members.

> “As a staff member, I’ll be thrilled to know that my company is capable of these things and employing futuristic technology” [Retailer H].

6.4.7.3.3 Creating communities

Creating communities or networking opportunities with the help of IoT, specifically smartphones, is a theme surfaced by 4 retailers. Retailer G explained,

> “Smartphones not just help in marketing but also is creating communities. Beyond Facebook, and helps creating communities like One-club, Fitness-group and so forth. It helps to keep the community active, at the same time contributing to social side”.

Retailer H also stated,

> “IoT helps place our staff in different professional networking opportunities”.

6.4.8.4 Freeing time to focus on more productive and innovative activities

Having time to think and learn is crucial for innovation (Lawson 2001). Gaining free time to focus on more constructive activities is another theme discussed by 5 retailers.

> “IoT applications frees people like me to actually invest time into kind of activities that I'm more worthwhile rather than administrative kind of activities” [Retailer A].
>
> “Before this integration of IoT devices, your problems were different. Your problems were like tracking a lost parcel or managing the warehouse or managing the store staff. Now what your problems are really getting more creative, that’s your problem. That means it's a great problem to have” [Retailer H].

6.4.8.5 Help in planning

IoT provides more accurate information for more effective planning (Ben-Daya et al. 2017). Ten managers spoke of IoT as a potential tool to plan their firm operations better.

> "The best thing you are going to get out of that is an accurate picture of what's going to happen in the future, predictions. It helps to identify the right product, helps to plan how many containers we need to bring, how many people we need in the warehouse to process the orders, how many trucks we need to deliver. It all helps with the planning process" [Retailer G].
>
> "I think it all comes down to adequate planning" [Retailer A].

6.4.8.6 Effect of IoT deployment on firm performance

The survey findings show that IoT improves supply chain processes to positively effect firm performance represented by economic, environmental and social measures. The finding is grounded on organisational capability theory which refers to how organisational capabilities directly or indirectly affect a firm's performance (Huo 2012). The literature argues that the firms are interested in deploying IoT in their logistics functions due to its potential to impart economic benefits to the stakeholders (Xu et al. 2014). The findings on the economic sustainability of firms due to IoT integration is endorsed on the themes of growth, cost reduction, return of investments and competitive edge in the interviews. However, the emerging effect is not limited to firms' economic sustainability. Managers' perceptions are that IoT also impacts social (particularly HR) and environmental dynamics to effect the triple bottom lines of firm sustainability. The literature reports that environmental impact is a key sphere in which IoT utility is transforming firms (Del Giudice 2016). Environment sustainability themes was addressed under the key sub-themes of reducing paper, reducing carbon footprints, energy saving and minimising wastage in the interviews. The literature argues that IoT is becoming very important in HR spaces as IoT can be applied in such circumstances as ensuring the safety of employees in hazardous working environments (Hwang et al. 2015). Accordingly, safety and job satisfaction were the key themes in social spaces that had HR implications. In addition, freeing time for more productive activities and help in planning are other firm performance dynamics that were found to add strategic value to firms.

6.5 Chapter summary

The purpose of the chapter was to provide an in-depth account to explain how IoT is currently deployed in diverse supply chain processes, integrating suppliers, internal firm processes and customers to improve supply chain performance and, in turn, firm sustainable performance. The chapter presented the findings from the interviews with 12 Australian retailers and a 3PL service provider. The findings suggest a positive relationship between IoT capability and the three dimensions of SCI to influence supply chain and firm performance. This interprets, explains and validates the positive association found in the quantitative study discussed in chapter 5. Thus, these qualitative finding support the quantitative survey findings.

An overview of contextual information was presented to provide an understanding of the studied environment. The interviews revealed that various forms of technologies under the IoT umbrella coexist in Australian retail supply chains and that they add capability to the current legacy of ICT. The findings indicate that all managers are aware of what IoT is and all have had some form of IoT deployed in their supply chain that serves as an extended ICT capability. The thematic analysis of interviews finds the participants need IoT for data capture and information sharing. While a few participants thought IoT was unnecessary or unaffordable due to the nature of their business, all uniformly believed that IoT is an effective approach to manage ever-advancing supply chain operations to gain competitive advantage, build brand integrity and promote economic growth, while preserving the environment and cultivating social aspects. Generally, all affirmed the importance of SCI, where the role of IoT is vital. All also revealed that IoT application is dependent on the business model and processes, industry sector and the nature of the operations.

Validation and interpretation of hypothesised relationships in the conceptual framework (Figure 3.1) was the key objective of this phase. While the quantitative findings in chapter 5 established the significant relationships between IoT and the three dimensions of SCI, this chapter used the interview results to establish the validity of these relations from the Australian retailer perspective. From the organisational capability theory perspective, IoT deployment integrates supplier, internal and customer business processes to add value to the existing capability of ICT for greater SCI. The participants agree that IoT’s capability to improve visibility of product flow, auto-capture, intelligence and sharing of information as additional capabilities help strengthen all dimensions of SCI. These outcomes are perceived to improve supply chain performance dimensions including cost, quality, delivery and flexibility and, in turn, positively affect the sustainable performance of the focal firms. The findings are consistent with organisational capability theory, where IoT providing additional capabilities to established ICT capability in strengthening integration capability of supply chains to ultimately improve firm performance (Huo 2012).

The next chapter will discuss the results of both quantitative and qualitative studies in detail, and the theoretical and practical implications of the findings.

Chapter 7
Discussion

7.1 Introduction

This chapter discusses the findings from the quantitative and qualitative phases of this study concerning the hypothesised relationships within the conceptual framework. The qualitative findings are used to interpret, support and validate the findings from the quantitative study (Flint et al., 2012). The empirical survey findings confirmed all hypothesised relationships in the conceptual framework. That is, this study demonstrates that IoT capability positively affects internal, supplier and customer integration, to influence supply chain performance, and, thus, it impacts positively on firm performance. The findings also confirm that IoT-enabled internal integration is positively and significantly related to IoT-enabled supplier and customer integration process.

The chapter is structured as follows. First, section 7.2 highlights important themes that were derived from the data to strengthen this investigation and the literature. Therefore, this segment discusses the general outcomes of both the quantitative and qualitative findings to feature some explanations that answer the research questions. Then the key findings on the tested conceptual framework are discussed in sections 7.3, 7.4, 7.5 and 7.6, each focussed on the hypothesised relationships, before they are synthesised in section 7.7. The qualitative results have been utilised, where they are applicable and appropriate, to validate, interpret and support the quantitative findings. Moreover, the existing literature and theory is referenced when relevant to explain the findings from both phases. Section 7.8 discusses the contribution of this study to the existing literature on ICT-enabled SCI to consider IoT as an ICT innovation, imparting greater understanding of how IoT functions and progresses within retail supply chains. Section 7.9 outlines the implications of the study findings for managers, industry associations and policy makers. Finally, section 7.10 addresses the limitations of the study and suggests avenues for further research.

7.2. Background overview on IoT in retail supply chins

First and foremost, all interview participants had a clear understanding of what IoT is all about and believed that IoT offered extended capabilities for data capture and transmission via the Internet. Their general perception was consistent with various scholars who identify this pervasive technology as a neoteric ICT innovation with capabilities beyond traditional ICT (Atzori et al. 2010; Borgia 2014). It is well established that ICT facilitates supply chain relationships and further integrates business processes (Chiang et al. 2014). The participating managers discussed IoT as a part of a larger ICT architecture. Consequently, middleware plays a major role in the integration of legacy technologies into new ones (Atzori et al. 2010; Ray 2018).

The sample survey of 227 and 13 interviewed managers, having multiple forms of IoT in their supply chain, confirmed the widespread diffusion of and familiarity with IoT across various retail sectors. Despite the technology being still in its infancy in some area of application (Xu et al. 2014), IoT has an influential presence in supply chain operations in the Australian retail sector with multitude new forms and applications (Atzori et al. 2012; Li et al. 2014).

All interviewees confirmed the promise of IoT as a valuable tool to further integrate their supply chain. The practitioners' convictions are consistent with scholarly arguments that IoT can synchronise information flow with physical flow for greater SCI (Ping et al. 2011; Yan et al. 2014). IoT has moved beyond the initial wave of RFID technology which enabled identification of individual items in supply chain operations (Mishra et al. 2016). The single item level identification via RFID did not exist in the Australian retail supply chains examined here; RFID was only in some cases for unit level identification (e.g., box, pallets, containers) as found in interviews. RFID was identified as being potentially useful in monitoring and managing stock levels. Therefore, item-level tagging, rather than carton or pallet-level tagging, should be considered to realise the potential of IoT (Tu 2018). Nevertheless, more popular forms of IoT technologies are in widespread use. They include location-based telemetry, smartphones, handheld devices, sensors and scanners, security and surveillance devices, and internet-based barcoding. The best value addition from IoT technologies could be derived when multiple forms are used in an integrated manner.

The negative environmental effect of having such vast range of electronic devices is well documented (Suresh et al. 2014). However, the interview findings suggest that there is a drive for consolidation of these multiple devices, mainly towards the multi-faceted smartphone. This consolidation may help slow the move forward of the planet becoming an impending e-waste dump yard.

Every firm in general is a producer as well as a user of information. Therefore, the literature argues that firms should generate and analyse the useful information internally and share it externally with supply chain partners (Wu et al. 2016). IoT has the capability to capture more in-depth data that ICT, as demonstrated by the interviews. The literature also identifies IoT's ability to collect deeper, more accurate data as its key strength (Verdouw et al. 2015). Massive amount of data captured by IoT devices to isolate valuable information (Tsai et al. 2014). Consequently, IoT, Big Data analysis and, especially, digitalisation have prompted a renaissance of knowledge in decision-making (Kaivo-oja et al. 2015). If the data captured via these smart devices is appropriately collected and analysed, it can provide unprecedented visibility for all aspects of the supply chain, including pre-emptive alerts of about internal and external occurrences that require speedy remediation (Ben-Daya et al. 2017). The interviews clarified the benefits of analysing the extra data that is captured by IoT, establishing its positive impact on areas such as forecasting and planning, operational, tactical and strategic decision making, evaluations of staff, instruments and processes and process improvement.

Notably, the interviewed managers believed that real-time streaming analytics and reporting was a major advancement in reporting, driven by IoT. The survey data also indicate that real-time streaming analytics is one of the key IoT technologies the retailers are looking to implement within the next 3 years. This reflects the literature on the impactful potential of real-time, context-responsive streaming analytics, as a prominent facet of modern IoT platforms (Ahlgren et al. 2016; Lee & Lee 2015; Taneja et al. 2015).

All the interviewed retailers had major part of their logistics functions (e.g., transport, warehousing) outsourced to 3PLs or even 4PLs indicating the widespread popularity of the outsourcing model. Outsourcing logistics functions has become the dominant choice in current supply chain structures (Ben-Daya et al. 2017; Jayaram & Tan 2010; Mentzer, Min & Michelle Bobbitt 2004; Yu et al. 2015). Prior research indicates that collaboration and integration not only need to be achieved within enterprise boundaries, linking external suppliers and customers, but also logistics service partners as well (Chen & Paulraj 2004; MacCarthy et al. 2016). Remarkably, 3PLs come in as early IoT adopters, with most retailers gaining their first IoT experience in supply chain operations via 3PL transporters. IoT in warehousing and transportation was initially introduced in the early 2000s with its basic capabilities (Ruan et al. 2012). Thus, Atzori et al. (2010) list the transportation and logistics domain as one of the first IoT application domains. Accordingly, the survey results indicate that GPS telemetry (in transport) is the most frequently used IoT form in Australian retail supply chains. Correspondingly, the interviews suggest that, in the present context, where technological aptitude is considered to be a key criterion for 3PL selection, it is an expected standard to have such technologies in place; 3PLs are compelled to furnish these technologies to secure outsourced contracts, and to survive and thrive in a competitive space.

The literature argues that the organisational nature of a firm may affect technology implementation and outcomes (Yu et al. 2016). However, no direct effect was found in the SEM analysis, testing the effect of control variables such as firm size and retail form on the performance attributes. Tu (2018) study found that coupled with external pressures, perceived benefits and costs are important determinants of IoT adoption intention in firms. Accordingly, all three themes came up during the interviews in discussions concerning rationales and obstacles for IoT deployment.

The overwhelming majority of the survey participants referred to improved overall business performance as the motivator for IoT adoption in their firms' supply chain operations. From the organisational capability theory perspective, firms strengthen core/lower order capabilities (in this case IoT adoption) with an ultimate purpose of improving their firm performance (Huo 2012; Rai et al. 2006). Likewise, the detailed themes found in the interviews identified efficiency, optimisation and visibility as key drivers for the implementation of IoT in their supply chain operations, eventually enhancing the firm performance. These findings are consistent with the literature, which argues that visibility, efficiency and optimisation are outcomes of IoT in supply chains (Atzori et al. 2010; Xu et al. 2014).

Despite managers viewing IoT in general as a sound investment which is becoming progressively more affordable, the cost of investment was the key obstacle for IoT adoption in the interviews, along with lack of managerial vision, managerial and employee resistance to change and the staff being scared of the technology. Other scholars have also found that obstacles that negatively affect IoT implementation decisions include cost of investment, employee resistance to change and the fear of unknown technology (Bardaki et al. 2012; Sundmaeker et al. 2010).

The participating managers blamed inadequate time and lack of incentive to learn new IoT technologies as key barriers to full capitalisation on existing technology deployment. Internet service quality, fear of sharing information and platforms and reluctance to change were some of the other reasons mentioned. The literature reports that there are many constraints which impede the most effective use of the technology we currently have although it does not specifically identify these constraints (Misra, Simmhan & Warrior 2015; Xu et al. 2014). Thus, IoT as additional capability needs to be well embeded in the supply chain processes to produce the best outcomes (Huo 2012).

Openness, interoperability, and standardisation are crucial concerns raised by the literature for the success of IoT architecture (Ahlgren et al. 2016; Atzori et al. 2010). Accordingly, lack of access to supply chain partners' systems, inadequately integrated systems, lack of technology standardisation and interoperability issues were identified as major difficulties for the progression of IoT in supply chain operations. Due to these issues, current IoT systems in supply chain operations appear fragmented, rather than fully interconnected within a unified platform with a common standard. Therefore, these technical issues challenge the interconnectedness of IoT devices (Weber 2010; Wu et al. 2016). Technology standardisation is key to eliminating these barriers (Borgia 2014).[11]

Supply chains are cross-functionally integrated to ideally optimise both data sharing and business processes (Angeles 2009; MacCarthy et al. 2016). However, the qualitative findings suggest that the retailers rarely provide real-time access to their raw data to their supply chain partners (e.g., suppliers) or share captured data with them. In contrast, managers are contented with in-house cross-functional data sharing. The literature finds however, they are unwilling to share information outside their own organisational boundaries (Mentzer, Min & Zacharia 2000; Nakauchi, Washburn & Klein 2017), particularly sensitive information (Ding, Parwada & Shen 2017; Kemppainen & Vepsäläinen 2003). However, there is recognition that organisations need to exchange information via integration processes, across firms to ensure a smoothly functioning supply chain (Näslund & Hulthen 2012). Retailers are happy to share the aggregated broad findings of in-house data analysis with supply chain partners for evaluation, planning, forecasting and process improvement purposes. The flow of data is estimated to be around 15-20% of the world's GDP (SDA National 2018). Thus, for smart organisations the focus is on ensuring knowledge integration is a key part of management (Kaivo-oja et al. 2015). Prajogo and Olhager (2012) found that information sharing has a significant effect on logistics integration. Correspondingly, information sharing over IoT platforms can happen between people, between people and things and between things (Lee & Lee 2015), providing a great platform for knowledge integration (Kaivo-oja et al. 2015). Therefore, it should be better exploited.

[11] EPC global is a subsidiary of the not-for-profit standards organisation GS1, supporting the standardisation of unique identifiers, called Electronic Product Code (EPC) (Atzori et al. 2010). GS1 that provides open standards for EPC-based RFID tags, barcodes, IPv4 or IPv6 as such (GS1 2016), which is advocated by many interviewed, and could be the key calibration enabler for the theorised personification of IoT, to allow interoperability among these fragmented platforms to achieve IoT's true potential.

7.3 Effect of IoT capability on supply chain integration

The quantitative results suggest that IoT capability positively affects the three dimensions of SCI - internal, customer and supplier integration. The qualitative findings also support and validate the findings of the survey. The interview analysis provides detailed evidence of IoT technology being deployed in Australian retail supply chains and how it is generally perceived positively in terms of current benefit and anticipated potential to further strengthen supplier integration, internal cross-functional integration and customer integration.

The positive effect of IoT capability on supplier integration was validated by interviews. IoT was perceived to be able to support retailers for supplier integration by helping suppliers to improve their operations to better fulfil retailer's needs, and improving interaction with suppliers, forecasting, inbound delivery process, receiving process and traceability. The survey findings also suggest that IoT capability has a positive and significant effect on internal integration. Likewise, the interviews also revealed IoT's positive contribution in in-house logistics functions such as warehousing/DC operations, inventory management and transportation and helping with in-store operations and identification. Importantly, the findings reveal IoT's potential in improving cross-functional communication among functional silos within the firm. The survey findings also revealed that IoT capability has a positive and significant effect on customer integration. The qualitative findings also reveal IoT's role as an in-store technology to help customers, how IoT is used as a promotional tool, IoT's role in improving the online presence of retailers and digital order making of the customers and how it helps in picking, despatch and deliveries. The key outcomes the retailers receive from IoT are the understanding of customer needs, ability to develop promotions and suggestions on what customer should purchase, improving customer service and satisfaction and to encourage reviews and to improve their customer ratings. It is evident that IoT has a big role to play in this rating-based economy to integrate the customers into a firm.

The literature argues that, even though the applications of IoT are still in their infancy (Atzori et al. 2010; Lu & Yang 2017), supply chains are progressively more digitalised as a result of exploiting the extended capabilities of increasingly affordable IoT technologies (Bardaki et al. 2012; Haddud et al. 2017; Verdouw et al. 2013) to address the information gap which exists in traditional supply chain ICT applications (Ben-Daya et al. 2017; Liu et al. 2015). The findings of this study endorse this argument that multifarious forms of technologies under the IoT umbrella coexist in Australian supply chains, as a pervasive technology perceived optimistically by the retailers.

More importantly, the findings empirically validate several IoT related studies. First, *conceptual* discussions, notions and arguments in the literature about its affirmative effect on SCI. This includes affirmation of Ping et al. (2011) argument that IoT strengthens the connection between the physical flow and the information flow via accurate real-time representation of supply chain entities in information systems; Reaidy et al. (2015) proposition of IoT infrastructure for collaborative warehousing; Yan et al. (2014) proposal of a novel intelligent SCI and management system which incorporates in-house operations, warehousing, manufacturers, suppliers and customers; Gu and Jing (2011) proposed management information system for fresh agricultural products in upstream aspects; Cui (2015) proposal to improve supply chain resilience and Liu and Sun (2011a) model for the management of an automobile parts vendor-managed inventory (VMI) system via superior information flow designed by IoT. Second, the findings empirically support the limited *laboratory-based* study outcomes on IoT's effect on SCI (Reaidy et al. 2015; Yan et al. 2014). Third, the findings are also consistent with the preliminary findings of the currently ongoing project using the *case study method*, indicating that SCI can potentially significantly enhanced by IoT data (Wakenshaw 2017).

The findings are consistent with earlier RFID-enabled SCI specific studies as well. With respect to the former see Angeles (2009), Wamba and Boeck (2008), Wamba (2012). With respect to ICT-enabled supply chain integrations, see Näslund and Hulthen (2012), Li et al. (2009), Kim (2017), Dong et al. (2009), Vanpoucke et al. (2017), Yu et al. (2016), Prajogo and Olhager (2012), Shatat and Udin (2012), Li (2015), Rai et al. (2006).

Flynn et al. (2010) argue that SCI is a multidimensional construct that can generate more accurate conclusions than using a unidimensional construct. Yu (2015) conceptualises SCI as a multidimensional construct to substantiate positive relationships between ICT implementation and the internal, customer and supplier integration. Thus, this study also investigated SCI as a multidimensional construct and the findings are correspondingly coherent with Yu (2015).

This study extends ICT capability further to include IoT as an additional capability in this integration study. Yu (2015) study is consistent with the organisational capability theoretical perspective proposed by Rai et al. (2006), where ICT is considered to be a lower-order organisational capability that can only have an impact on performance through a higher-order organisational capability (in this case, integration). Yu et al. (2016) employed a resource-based view (RBV) perspective in their study to consider ICT capability as "a firm's ability to mobilise and deploy ICT-based resources in combination or co-present with other resources and capabilities" (Bharadwaj 2000, p. 171) (see also Dong et al. (2009). From an organisational capability perspective, SCI is a capability that depends on the extent of IoT infrastructure as organisational resources. Bharadwaj (2000) argues that ICT has positive effect on firm performance when coupled with other resources like human and financial resources. Likewise, the common stipulation in the supply chain management literature is that ICT implementation itself cannot generate performance; its alignment and ability to facilitate SCI is what renders positive outcomes (Li et al. 2009; Prajogo et al. 2016; Rai et al. 2006). This study makes a case for IoT deployment along these lines complementing ICT capabilities currently in place to realise new benefits. This study uses organisational capability theory to consider IoT as an extension of ICT as a lower-order/core organisational capability to enable a higher-order/dynamic organisational integration process capability.

ICT implementation allows supply chain entities to integrate and share information more effectively (Yu 2015). IoT platforms further extend the reach of ICT systems beyond networked computers to include ubiquitous devices with data capture, transmission, information processing and actuation capabilities. Thus, IoT facilitates information integration across supply chains, along with various coordination mechanisms among supply chain entities. For instance, smartphones are gaining momentum as a singular device to integrate supply chain activities and actors, particularly in the customer integration space. The existence of IoT's functional capability to reinforce the ICT capability of organisations was perceived by the participants in this study to act as an enabler of supply chain process integration.

As this study demonstrates, IoT has helped to shape the structure of supply chains, via its capability for internal integration as well as external integration with suppliers and customers. This has been enabled by the capture, timely availability and analysis of data in real time, creating greater efficiencies in decision-making and control. Information availability, in real-time where possible, and communication to achieve supply chain visibility, are necessary to achieve strong integration (Van Breedam 2016). It can be argued that, going beyond the information flow, IoT's autonomous actuation ability has the potential for self-governing collaborative control of the physical and financial flows of supply chains, via the information flow and ambient intelligence for even greater SCI (Ben-Daya et al. 2017).

Given that supply chains are generally demand-driven, end-customer demand information is the most vital information in supply chain management systems (Wu et al. 2016). When firms are exploring cheaper and smarter options to connect with customers, omnipresent smartphones, as a device that is paid for by the customer and accompanies the customer all the time, can be considered the key enabler of stronger customer integration. It is evident in the study data that, as an integration device, smartphones are amply exploited for variety of integration subtleties, and further effort is being made into making incorporated them further in the future. Initiatives incorporating the smartphone are gathering momentum as the key personal identifier, communicator and payment gateway, even the Amazon Go concept store established the smartphone as its key enabler (AAP 2018). Alongside existing forms, such as RFID, GPS, beacons, sensors, scanners and identifiers, there are many new IoT forms joining in each day for the purpose of integrating the ever-important customer.

7.4 Relationship between IoT-enabled internal integration and external integration

No previous study had tested the conceptualised effect of ICT-enabled internal integration on external integration. The findings of this suggest that IoT-enabled internal integration has a positive effect on IoT-enabled external integration. The quantitative results signify that IoT-enabled internal integration has a positive effect on both IoT-enabled supplier integration and IoT-enabled customer integration. The qualitative findings support and validate the survey findings and describe how IoT-enabled internal integration is perceived to positively influence supplier and customer integration. Investment in ICT improves the likelihood of the firms achieving cross-functional internal integration (Yu 2015), which in turn strengthens external integration with upstream suppliers and downstream customers (Huo 2012). Likewise, deployment of IoT within the organisation further strengthens integration with customers as well as suppliers. Organisations must develop internal integration capabilities first, in order to achieve meaningful external integration (Huo 2012; Zhao et al. 2011). Yu (2015) maintains that the more an organisation invests in ICT, the more it is likely that it will achieve internal integration within cross-functional areas, which in-turn intensifies external integration with suppliers and customers.

This study findings are consistent with existing SCI conceptual discussions. The findings of this study extend the literature to posit that, as an extended ICT capability, IoT-enabled internal integration has a positive effect on IoT-enabled supplier and customer integration. Existing literature shows that firms should integrate their internal business processes to facilitate information sharing with external partners (Chiang et al. 2014). Firms must first consider internal integration, prior to extending to external integration with their supply chain partners (Huo 2012; Stevens 1989). Internal cultures (both attitudinal and process oriented) must be aligned prior to the inclusion of supply chain partners in the integration efforts (Huo 2012;

Tracey 2004). Successful external integration in a supply chain, is, therefore, to a significant degree, linked to internal process integration (Huo 2012; Su & Yang 2010). Thus, intra-firm integration is the foundation for broader integration across the supply chain (Schoenherr & Swink 2012; Simchi-Levi et al. 2008) (see also Ataseven and Nair (2017); Chang et al. (2016)). More importantly, many studies (Ralston et al. 2015; Schoenherr & Swink 2012; Yu et al. 2013; Zhao et al. 2011) find that internal integration substantially impacts customer and supplier integration. Huo (2012) study, from which the tested conceptual framework is adopted, also finds that internal integrative capabilities provide the foundation for developing external integrative capabilities.

The findings are also coherent with the organisational capability perspective. Organisational capability theory suggests that internal integrative capabilities (e.g. ICT, human resources) can directly affect external integrative capabilities. This is owing to information exchange and a culture of collaborating extending internally from the individual firm to the entire supply chain (Huo 2012; Zhao et al. 2011). Therefore, the findings support the organisational capability theory perspective that an organisation with a high level of internal integration capabilities is more capable of achieving a high level of external integration capabilities (Zhao et al. 2011). Moreover, the integration capabilities of suppliers and customers represent an 'outside –in' capability that can complement the 'inside- out' internal integration (Chang et al. 2016). Consequently, Huo (2012) extends the organisational capability theory to argue that internal integrative capabilities underpin SCI capabilities. The findings of this study extend organisational capability theory to posit that organisations can use higher order/dynamic internal integration strengthened by lower order/core IoT capability as a foundation from which to develop external integration facilitated via IoT and to thus improve external integration.

Internal integration via IoT can therefore be considered to be an important advancement of digitally-enabled SCI, facilitating IoT-enabled integration of the entire supply chain. Ataseven and Nair (2017) argue that excessively prioritising external integration with customers and suppliers may cause organisations to miss out on opportunities to realise competitive advantages by fostering internal integration. The assertion is applicable to these findings as well. Overcoming cross-functional barriers by strengthening the integration of in-house operations (including cross-functional teamwork and communication) may foster better outcomes when using IoT in digitally synchronising with external supply chain partners (Ben-Daya et al. 2017; Zhao et al. 2011). The findings of this study suggest that IoT can be a great tool to support this synchronisation. Internal integration requires greater investment in ICT internally (Yu 2015). Likewise, a firm' internal leveraging of IoT's potential is likely to influence the development of the firm's relationships with external customers and suppliers using the IoT platform. For example, Retailer G's diverse IoT systems has made them feel ahead of competition, and able to provide forecasting data on customers two years in advance to their suppliers, who are awaiting downstream visibility. This higher level of information sharing can possibly minimise the bullwhip effect further upstream the supply chain (Datta & Christopher 2011; Vanpoucke et al. 2017). It is also evident that Retailer D integrates many IoT devices internally (data capturing and sharing real-time analysis, progressing sales via a smartphone app among cross-functional teams), allowing them to extend the same system to customers' mobile phones to integrate downstream operations and then provide that visibility to upstream suppliers via the same app.

While one group of scholars espouses the notion that internal integration is the foundation for SCI, some authors—without disagreeing that internal integration is important—imply that external integration can drive internal integration (Näslund & Hulthen 2012). From this study, is evident that some firms who are not well integrated internally can still linked be to an external partner's IoT platforms, thus absorbing the partner's capabilities to improve external integration. This means that SCI capabilities can be obtained with the help of external integrative capabilities. However, not having well integrated real-time systems has prevented them from capitalising on those external integrative systems. For example, Retailer L uses a delivery track and trace platform to integrate with the customer. However, they were not able to exploit its full benefit, owing to a manual warehousing system that could not provide live inventory data. Thus, they are selling the products that they do not have and having to cancel customer orders. Retailer L voiced the need for internal integration via IoT deployment to remedy that situation, pointing to external systems as an example. Working with superior upstream and downstream integration systems can inspire employees to nominate such systems for internal operations as well. Thus, the firms that are poorly internally integrated gain some benefits from external SCI; however, sound internal integration is still necessary (Schoenherr & Swink 2012). Richey et al. (2010) and Stank et al. (2001) advise firms to focus on both internal and external integration at the same time.

Huo (2012) argues that his findings that internal integration has a positive effect on external integration validates the management shift from a singular organisation to the management of an entire supply chain. The findings of this study argue for a management shift to the entire supply chain, rather than an individual organisation, in a digitally-enabled integration context when it comes to IoT deployment and resource sharing. Therefore, in dynamic and competitive environments, the shift towards managing in-sync should build momentum, inspiring supply chains to share and pool capabilities.

7.5 IoT-enabled supply chain integration and supply chain performance

The findings suggest that the three dimensions of IoT-enabled SCI positively effect supply chain performance. The quantitative results indicate that IoT-enabled supplier, internal, and customer integration exhibit a positive and significant effect on supply chain performance. Further, IoT-enabled external integration (i.e. supplier and customer integration) is stronger than IoT-enabled internal integration. The thematic analysis of interviews supports the quantitative findings. The participating managers believe that IoT technologies provide additional capabilities via auto-capture (with human resource implications), real-time visibility and improved communications for greater SCI to improve supply chain performance, via cost, quality, delivery, flexibility, and customer service dynamics. The findings are in agreement with earlier studies (Ben-Daya et al. 2017; Dweekat & Park 2016; Liu & Gao 2014) which argue that IoT technologies can improve supply chain performances.

The prior studies have shown no empirical evidence of effect of IoT-enabled SCI on performance. However, there are conceptual discussions about IoT's capacity to improve digitally-enabled SCI that imparts supply chain performance (Ping et al. 2011; Yan et al. 2014). Ping et al. (2011) argue that IoT's ability to synchronise the information and physical flows can further improve the efficiency and effectiveness of supply chains. Similarly, Reaidy et al. (2015) propose IoT-enabled infrastructure to improve the competitiveness of warehouses. Gu and Jing (2011) propose IoT to increase SCI level, perfecting the monitoring of the fresh agricultural products for quality control and reducing supply chain costs with improved efficiency.

This finding also supports the limited laboratory-based study outcomes of the IoT integration effect on supply chain performance (Reaidy et al. 2015; Yan et al. 2014). Reaidy et al. (2015) claim that IoT can improve the ability to respond to dynamic supply chain situations. Yan et al. (2014) also find that IoT-enabled integration can support physical resource management, in turn improving overall supply chain performance. Yet, there is no evidence or empirical studies testing the effect of IoT on supply chain performance (Ben-Daya et al. 2017; Mishra et al. 2016).

The finding is also comparable to ICT-enabled supply chain literature, including the existing literature on RFID (Vlachos 2014; Wamba 2012; Wamba & Boeck 2008). Zhang et al. (2011) undertook a systematic review of literature and found that there was a positive influence of ICT on supply chain performance. Importantly, Li et al. (2009) found that the effect of ICT on supply chain performance is not direct, but it is ICT-enabled SCI that influences supply chain performance. Thus, the findings that IoT-enabled SCI is positively related to supply chain performance is consistent with Li et al. (2009) findings (see also, Prajogo and Olhager (2012), Li (2015) Vanpoucke et al. (2017), Shatat and Udin (2012)).

Most ICT-enabled SCI studies consider SCI as a unidimensional construct. Out of the limited studies that considered SCI multi-dimensionally, Yu (2015) finds that ICT-enabled internal integration is positively related to operational and financial performance, but ICT-enabled supplier and customer integration have no effect on those performance dimensions. Similarly, Vanpoucke et al. (2017) suggest that ICT integration in inter-firm relationships increases the speed and accuracy of supply chain processes, and the benefits from upstream partners integration are relatively stronger than downstream partner integration. Li (2015) claims that ICT in internal integration significantly and positively affects operational performance. Huo (2012) reveal internal integration capabilities as the major drivers of company financial performance. Flynn et al. (2010) also find that SCI is related to operational and business performances, yet, internal and customer integration are more strongly related to performance improvement than supplier integration.

Results in this study show that the use of IoT for integration with suppliers and customers has a stronger impact on supply chain performance than internal cross-functional integration. In contrast to multi-dimensional SCI studies, this finding suggests that all three dimensions of IoT-enabled SCI influence supply chain performance. Specifically, both supplier and customer integration show a stronger relationship than internal integration with supply chain performance. Supply chain managers perceive that their firms gain more from IoT technologies in relation to external integration efforts than internal integration.

Due to affordable IoT technologies (e.g., sensors, actuators, RFID, CCTV camera), supply chains are progressively more virtualised in response to market challenges (Verdouw et al. 2013). Virtual integration represents integrating supply chain partners through ICT for tighter supply-chain collaboration (Wang et al. 2006). Wang et al. (2006) virtual integration theory proposes that virtual representation of supply chain entities can improve supply chain performance. Integration and control are based on connectivity in the flow of information in the virtually-integrated supply chain – ownership of information does not necessarily matter (van Hoek 1998, p. 509). The IoT unbrella of technologies emerges as an opportunity to virtually represent supply chain entities.

Transportation remains a costly and critical part of supply chain management. Jayaram and Tan (2010) find that firms that integrate 3PLs in their supply chain management perform better. Thus, pervasive IoT can help in integrating the logistics flow. For example, upcoming driverless or autonomous transportation with IoT deployment can facilitate supply chain efficiency and transparency (Druehl, Carrillo & Hsuan 2017). When it comes to logistics intermediaries, retailers draw on external 3PLs those who deploy IoT capabilities. IoT-enabled auto-capture, track-and-trace, route optimisation, auto-alert, planning efficiency reportedly resulted in cost reduction, delivery and product quality, agility, and thus customer satisfaction, benefiting the entire supply chain. More importantly, integration of technologies such as retina scanners, facial recognition identifying drivers' fatigue, GPS tracking and real-time engine analysis for vehicles roadworthiness make the road a safer place for everyone.

The 'theory of integration' confirms that there is a significant benefit to integrating supply chain operations (Frohlich & Westbrook 2001; Schoenherr & Swink 2012). IoT can be a digital enabler for internal integration via encouraging information sharing and collaboration between various organisational functions from human resources, to finance, through to logistics. Likewise, IoT applications can speed up operations and improve service levels and share information to improve communications with customers. Supplier coordination and collaborative processes management using IoT technologies benefit all partners. Increased information sharing and collaboration improves supply chain performance (Zhang et al. 2011). Ataseven and Nair (2017), in their literature review, found a positive relationship between SCI and operational, financial performance or cost, quality, delivery, flexibility performance. Therefore, collaborative management via the IoT platform can improve the supply chain performance dimensions like cost, quality, delivery, and flexibility

7.6 IoT-enabled supply chain performance and firm performance

The findings show that IoT-enabled supply chain performance has a positive effect on firm performance. The quantitative results reveal that IoT-enabled supply chain performance exhibits a positive and significant effect on firm performance. The thematic analysis of the interviews also supports these findings. The IoT-enabled supply chain does not just affect a firm's financial bottom-line, but also influences its environmental and social attributes.

Therefore, IoT deployment can be considered to be a supply chain strategy that helps improve the environmental, social, and economic goals of firms (Carter & Rogers 2008; Elkington 1997). The interview analysis reveals that IoT in supply chain operations help firms improve their financial performance via cost reduction and competitive edge to enable company growth and return on investment. In addition, IoT is likely to improve environmental sustainability via paperless operations, reducing carbon footprints and energy consumption and minimising waste. Further, it helps to improve social performance by improving safety, job satisfaction and creating communities.

These findings resonate with earlier studies that argue that improving supply chain performance via IoT can improve firm performance (Lee & Lee 2015; Zhou et al. 2015b). For example, IoT can improve performance via business process management (Del Giudice 2016), knowledge management and integration practices by combining IoT, Big Data and management systems (Kaivo-oja et al. 2015). The findings empirically validate many IoT-related conceptual discussions (Del Giudice 2016; Kaivo-oja et al. 2015; Lee & Lee 2015), by establishing the positive effect of IoT deployment on firm performance.

The IoT-enabled SCI and firm performance relationship is coherent with prior studies in relation to ICT-enabled integration and performance. Rai et al. (2006) find that ICT-enabled SCI impacts firm performance positively. Dong et al. (2009), in their empirical study, find that digitally enabled SCI is related to firm performance improvement. Yu (2015) finds that ICT-enabled internal integration has a positive effect on both operational and financial performance. Subsequently, Kim (2017) clarifies that ICT does not directly influence firm performance, it is rather manifested through its deployment in functional integration. This study investigates emerging IoT technologies and the ways in which they integrate into the current ICT systems to improve supply chain performance, and in turn firm performance. This study argues that advancement in technologies, such as IoT, are gaining ground in logistics activities which were previously not accessible. Accordingly, real-world deployment of IoT supports firm strategy for SCI that improves supply chain performance and firm performance.

From the organisational capability theory perspective, this study argues that IoT deployment enhances a firm’s capability in digital integration and improves both the performance of the supply chain and firm performance. The use of IoT in the mainstream integration mechanisms supports the earlier studies (Huo 2012; Rai et al. 2006) who have claimed ICT deployment as a higher-order organisational capability. Interview results show that real-world deployment of IoT technologies can reduce cost, maintain quality, improve delivery efficiency, make the supply chain flexible and responsive and help customer services to improve the economic, environmental and social dynamics of the firm. IoT releases time for productive and innovative activities and helps in planning in many levels. Thus, a collaborative relationship with shared IoT platforms, data, and investment costs can benefit all partners in the supply chain, including customers, logistics service providers and suppliers.

IoT-enabled supply chains can drive firms towards their business objectives. This digitalisation of overall supply chain operations using IoT technologies can make firms more responsive towards customer needs and competitive in the market place. The interviews reflect that customers are "brutal" in their ratings, thus forcing firms to adopt and deploy technologies to make sure the service standards are maintained, exceeding customer expectation. Therefore, IoT can be a formidable digital enabler for firms' competitive edge.

7.7 Summary discussion

The ICT-enabled SCI has received a significant attention in operations and supply chain management literature since 1980's (Narasimhan & Kim 2001; Swanson et al. 2018). However, technological advances with added capabilities have recently emerged to intensify the dialogue. Existing ICT environment is transforming, where old legacy systems and new IoT technology are deployed collectively to provide heightened understanding and predictive capability (CSIRO 2018). The literature is, however, deficient in embracing any emerging technology to complement existing ICT capabilities. IoT, as one of the latest technological advancements, appears to be paradigm shift in a number of ways including supply chain and logistics management (Ben-Daya et al. 2017). IoT has the ability to bridge the divide between the virtual and physical worlds (Hofmann & Rüsch 2017; Mattern & Floerkemeier 2010), to synchronise the information flow with the physical flow impacting on performance (de Vass et al. 2018; Ping et al. 2011). IoT is an emerging but ever pervasive technology platform, linking the physical and digital worlds in a network of sensors, smart objects, smartphones, wearables, and nearables. However, the business application purview of IoT from the supply chain perspective is yet to enter mainstream research (Mishra et al. 2016). The academic literature (Ben-Daya et al. 2017; Mishra et al. 2016) has produced very little empirical evidence to theorise the effect of IoT on supply chain performance. This is a gap in current research in supply chain management and integration. In an attempt to address this gap in the scholarly body of literature, this study, supported by organisational capability theory, undertakes empirical modelling to understand the value-adding capabilities of emerging IoT in the digital integration of supply chain functions. In other words, how IoT capability can impact on SCI that in turn enhances both supply chain and firm performance. The study used Australian retail industry perspectives.

IoT is a “ubiquitous Internet connected platform of objects (things) that can be virtually represented any-ware any-time to provide autonomous real-time intelligence” (Atzori et al. 2010; Ben-Daya et al. 2017; Verdouw et al. 2016; Vermesan et al. 2011). The principle is that everyday objects are converted to uniquely identifiable smart objects that are able to detect information from the environment, interconnect with each other through the Internet and conduct real-time streaming analytics to impart intelligence to help control the physical world. This transition to IoT deployment multiplies the scope of data capure with improved timeliness, depth, quality and autonomy, in contrast to traditional computer-based static ICT with heavy reliance on manual data entry. The common goal explicated in the IoT literature is to build a ubiquitous society through an immersive connection of everyone (“people”) and everything (e.g., systems, machines, equipment and devices) without the aid of human intervention, to provide intelligent social and commercial services. Its widely transliterated ability to independently communicate using any available Internet service, analyse data to impart intellect or to independently actuate makes IoT a complete autonomous infrastructure.

IoT as this autonomous infrastructure can provide profound, precise, real-time intelligence at a negligible cost. This transition has not just improved the richness and speed of the information but has also reached places that are humanly impossible due to physical and practical constrains. Co-existence of IoT functional capability along with ICT capability of organisations is perceived to enhance integration capability. IoT is viewed as added components to the exiting ICT infrastructure to make them proficient in data capture. The findings empirically validate that IoT capability positively affects the three dimensions of SCI (supplier, internal and customer integration) to improve supply chain performance, in turn impacting firm performance. While SEM modelling confirmed all hypotheses in the study, the interview results were used to validate these quantitative findings.

The framework adopted in this study is built upon a central idea of SCI model used by Huo (2012, p. 600), who tested the effect of integration on firm performance from a manufacturing industry perspective. Using an organisational capability theory perspective, Huo (2012) finds the positive effect of SCI on performance. Earlier, Rai et al. (2006) demonstrated that ICT is a lower-order organisational capability which enables a higher-order organisational integration capability affecting firm performance. The results of this study extend ICT capability further to include emerging IoT technologies. IoT has the potential to connect the physical items with the digital world, specifically in the field of logistics, with increased sensing, networking, and communication capabilities (Da Xu, He & Li 2014; Hopkins & Hawking 2018). The findings supported several IoT-related conceptual discussions (Ping et al. 2011) and laboratory-based study outcomes (Reaidy et al. 2015; Yan et al. 2014). The result is consistent with many prior ICT-enabled digital integration studies that demonstrate that ICT is positively associated with performance through SCI (Kim 2017; Li et al. 2009; Rai et al. 2006; Yu 2015). Of course, Kim (2017) and Li et al. (2009) claim that there is no direct relationship between ICT and performance. Further, Yu (2015) confirms the effect of ICT on the three dimensions of SCI. Now the existence of pervasive IoT functionality adds to the traditional ICT capability and acts as an enabler of internal and external supply chain process integration. Within this framework, while a multitude of innovative and powerful forms of IoTs are progressively joining the ever expanding existing IoT umbrella of technologies, the smartphone is gaining momentum on the IoT platform.

Organisational capability theory suggests that internal integrative capabilities affect external integrative capabilities, namely supplier and customer integration (Huo 2012; Zhao et al. 2011). Huo (2012) study findings confirmed the theory. Yu (2015) supports the notion that ICT deployment in internal integration effects external integration with suppliers and customers. The findings of this study extend the academic body of knowledge to theorise that IoT-enabled internal integration has a positive effect on IoT-enabled supplier and customer integration. Deploying IoT as a platform for firms' internal cross-functional integration is likely to encourage integration throughout the entire supply chain. However, the firms with poor IoT deployment internally may secure some gains by integrating with external partners via an IoT platform or even piggybacking on their systems. Nonetheless, the likelihood of performance gains is much higher if thorough internal integration is formed (Schoenherr & Swink 2012). In effect, linking to 3PL or 4PL firms' systems seem to be the new trend in current retail environment, with retail firms exploiting external partner capabilities. This emergence of external service providers to share and pool capabilities can make the IoT platform accessible for all, even the retailers with depleted technology investment capabilities, to integrate their supply chain operations.

Organisations should revisit and reconfigure supply chain internal and external integrative capabilities to build resilience and respond to, a dynamic operating environment (Huo 2012; Teece, Pisano & Shuen 1999) with the intention to improve performance in a supply chain. As an emerging ICT development, IoT has transformed supply chain management with its ability to capture in-depth data and transfer it in real-time anywhere, anytime, for better supply chain control, decision-making and collaboration. With this enhanced, fast and in-depth information flow facilitated by the IoT platform to complement the traditional ICT, organisations are more likely to manifest effective SCI to acquire and create information much effectively. Thus, digitally-enabled SCI is further strengthened via IoT platform which can help upgrade supply chain intelligence in a rapidly evolving environment to reconfigure, transform and improve business processes to conduct effective operations. With enhanced quality and speed of information transmission and processing, IoT further complements the key objective of ICT implementation: to moderate supply chain uncertainty by reinforcing real-time decision making (Prajogo & Olhager 2012).

Literature investigates the effect of ICT-enabled SCI on supply chain performance while others explore its impact on firm performance. Zhang et al. (2011) review of survey-based empirical literature on digitally-enabled SCI found that the measurements and constructs used (e.g. ICT, performance) vary from one to other. Yu (2015) investigated the concurrent effect of three dimensions of ICT-enabled SCI on a firm's operational and financial performance, while Li et al. (2009) examined the effect of digitally enabled SCI on supply chain performance and others (Kim 2017; Rai et al. 2006) examined its effect on firm performance. Consequently, Qrunfleh and Tarafdar (2014) used a conceptual model representing ICT strategy to improve supply chain performance, that eventually impacts firm performance in sequence. These studies have used ICT (e.g., EDI, WMS, ERP and B2B portal) as the backbone of information exchange within the firm and between partner firms connected via Internet. But how do IoT technologies fit into this network of information exchange? This study argues that IoT plays an important role in tracking across the supply chain, where increasing numbers of objects carry barcodes, RFID tags, actuators, IP-cameras and sensors which generates data (Atzori et al. 2010; Da Xu et al. 2014; Hopkins & Hawking 2018; Razzaq Malik et al. 2017). This study finds that retail firm managers perceive IoT deployment as a data-gathering and communication capability which improves supply chain performance through data-driven decision making.

Similar to ICT's primary influence on business processes to improve supply chain performance, deployment of IoT *per se* is perceived to have a positive influence on performance. From the organisational capability perspective, a higher-order integration mechanism is achieved by a lower-order IoT capability to positively impact on performance (Huo 2012; Rai et al. 2006). These dynamic organisational capabilities can directly influence a firm's competitive advantage (Parida et al. 2016). While the supply chain strategy is to enhance performance by focussing on cost, quality, delivery and flexibility dimensions (Gunasekaran et al. 2004), it attempts to align with firm objectives of improving triple bottom line performance to generate environmental, social, and economic benefits (Carter & Rogers

2008; Elkington 1997). Thus, IoT is likely to have an impact on the sustainable competitive performances of firms by improving the performance of their entire supply chain.

It is well theorised that firms must initially foster internal integration before they can develop and leverage external integration (Ataseven & Nair 2017; Huo 2012; Yu 2015; Zhao et al. 2011). If firms have weaker internal integration, it makes difficult to exchange information with their customers or suppliers (Huo 2012). Yu (2015) prioritises internal integration in traditional ICT contexts. Then again, IoT-enabled supplier and customer integration affects supply chain performance more significantly than IoT-enabled internal integration. Therefore, within the IoT context, a unified approach of integration along the supply chain seems to grant greater benefits for supply chains in general and individual firms specifically. Thus, it makes perfect sense to suggest an integrated strategy for IoT implementation within the firm and upstream and downstream to gain the best outcome. The finding rationalises Flynn et al. (2010) argument for conceptualising SCI as a multidimensional construct, rather than a single construct, to demonstrate more accurate and unambiguous conclusions.

IoT is grounded in physical devices communicating with each other by sharing information over the Internet (Borgia 2014). The conception is that all supply chain partners integrate on this single digital IoT platform at their level and establish a network that integrates suppliers, manufacturers, retailers, logistics service providers and customers (Borgia 2014). The results suggest a collective management of the entire supply chain over IoT-enabled digital integration.

The effective and efficient operation of a supply chain depends on the swift movement of material flows by bringing together information, physical and financial flows (Rai et al. 2006). IoT captures data, supports internal and external information sharing between partners, and generates intelligence support via real-time analytics for effective decision-making based on data.

Many scholars have emphasised the value of IoT technologies in supply chain operations in general (Atzori et al. 2010; Borgia 2014; Haddud et al. 2017; Zhou et al. 2015b) and retail chains specifically (Lee & Lee 2015; Yu et al. 2015). This research thus reinforces the IoT adoption strategy that can improve SCI. Interviews identify real-time visibility, auto-capture and inter-and intra-firm communication and collaboration as key additional capabilities IoT presents within the current supply chain context. The finding further highlights the potential when IoT's conceptualised intelligence and automation comes in to fruition. As information sharing and collaboration among devices via IoT platform is conceptualised (Lee & Lee 2015), IoT technologies not only improve traceability and strengthen visibility, but also provide for autonomous controllability option in supply chain operations (Pang et al. 2012; Xu et al. 2014), with its ability to take action on synthesised information (Atzori et al. 2010; Sheth 2016). Futuristic innovations such as driverless transportation are simple examples of this ability (Druehl et al. 2017). On top of smart objects, another fundamental element of the IoT vision is machine-to-machine (M2M) interactions (Borgia 2014). Therefore, it can be argued that, going beyond strengthening information flow, IoT's actuation ability has the potential for autonomous control of the physical flow.

Alfalla-Luque et al. (2013) argue that SCI is a result of human interaction, which can be supported, but not be replaced, by technologies. On the contrary, the true vision of IoT is to capture data, communicate with other devices, synthesise data, reason and react independently (Luo & Wang 2012; Moreno et al. 2014). This futuristic potential will strengthen SCI at minimum or no human intervention, when machines take over a key part of this collaborative inter- and intra- organisational decision-making and operational process. Therefore, the future IoT-enabled SCI discussion should perceive integration in its entirety, considering information exchange about flow of goods.

Despite its potential, which is yet to be realised fully (Atzori et al. 2010; Lu & Yang 2017), this emerging IoT platform has already demonstrated its capability within the supply chain management sphere in terms of improving visibility, auto-capture, intelligence and partner communication in contemporary supply chains. Its just-in-time (JIT) communication capability can help minimise inventory levels at each juncture of the supply chain (Furlan, Vinelli & Dal Pont 2011). IoT can be deployed to efficiently inform physical flow status between supply chain partners, and collaborate with logistics service providers, minimise inventory holdings that can positively impact overall cost and developing a delivery schedule. IoT-enabled supply chain performance may then influence firm performance.

Interview results indicate that people are becoming less interactive with people and more with technological devices. IoT emerges as a potential solution for this new communication between people within supply chain. Traditional communication methods such as direct conversations or even conventional ICT forms, for example, telephone conversations and fax are becoming obsolete. The new generation (e.g., Gen Y and Z) barely tolerate email or desktop computers, instead favouring the smartphone as the primary communication alternative. Thus, to satisfy their preference, the smartphone can be considered to be the best practical option for future integration technologies. Everything will consolidate to a smartphone, as the only 'thing' that people carry. A few years ago, Google glass was introduced as an IoT alternative, yet was not able make huge impact. Until a more practical, user-friendly and relatively affordable option is innovated, smartphones seem to be the universal integrator for people in supply chains, including operators and customers, to integrate with the multitude of other IoT forms and devices in the value chain.

In the long run, technologies such as 3D printing will reshape how supply chains operate, with manufacturing moving further towards the customer, and the role of the logistics shifting from delivering the finished products to printing supplies (Van Breedam 2016). Thus, IoT can be the facilitator of the transaction of the design, as well as the just-in-time delivery of a range of raw materials. The momentum in ICT development in general enhances the capability of supply chain management and its integration (Van Breedam 2016). Thus, a multitude of innovative forms joining in under IoT umbrella of technologies with diverse means of connectivity and heightened functionality, with potential to be anywhere anytime, will improve the degree and the speed of information flow within supply chains resulting in more the efficient, responsive and resilient flow of goods. The evolution of IoT technology may improve supply chain operations by reinforcing ICT architecture, offering in-depth supply chain visibility in real-time, furnishing end-to-end span of autonomic control, beyond the first-tier partners.

7.8 Theoretical implications

Although supply chain management academics encourage methodological diversity, mixed methods research is rarely utilised in supply chain management research (Flint et al. 2012; Golicic & Davis 2012). Likewise, there are limited ICT research employing mixed methods (Venkatesh et al. 2013). Moreover, interdisciplinary studies representing both emerging technology and supply chains are rare (Linton 2017). Therefore, this research advances SCI research and the supply chain management discipline, by using mixed research methods to offer empirical evidence to validate and explain how IoT capability effects SCI to improve the performance of the entire supply chain, in turn influencing firm performance.

This research makes several noteworthy theoretical contributions to the supply chain integration literature and information systems (IS) literature. First, the literature on SCI (i.e. integration with external suppliers and customers, and integration of internal functions) so far has referred to ICT as an enabler where the technologies remain conventional in relation to data capture and sharing. Technologies such as email, fax, EDI, WMS, and ERP have facilitated information exchange. Such ICT-enabled integration studies lack the adoption of emerging technologies such as IoT. IoT technologies such as sensors, actuators, cameras, smartphones are able to connect physical ‘things’ to the digital world over Internet. These devices have the potential to capture and transfer data over the Internet. The much-discussed supply chain integration has yet to see the full benefits of this emerging technologies. The literature is quite rhetorical on the adoption and deployment of IoT in supply chain management and its integration specifically. Although IoT has been advocated for its capability to collect, store and transfer data online through Internet protocols, no such empirical research has been published so far to address how IoT can integrate supply chain partners for performance improvement. Further, the literature is so far limited to IoT's technology applications. This study has examined IoT in an empirical framework to see its significant effects on performance improvement. Therefore, IoT-enabled SCI for improving supply chain performance and firm performance is unique in this research. IoT technologies are not just a replacement for ICT *per se* but bring in a whole range of sensory technologies to interact with surrounding objects and enhance data capture and transmission capabilities. Results indicate that IoT adoption is positively associated with supply chain process integration of internal functions, supplier processes and customer processes. The integration thus achieved is likely to have positive influences on supply chain performance and firm performance.

Secondly, this study argues IoT deployment is an organisational capability which has not been studied previously in relation to supply chain integration. From a resource based view derived organisational capability theory perspective, supply chain integration is a capability of organisations, improved by having IoT technologies as organisational resources (Huo 2012; Rai et al. 2006). As ICT-enabled integration positively impacts supply chain performance (Li et al. 2009; Rai et al. 2006; Yu 2015), adoption and deployment of IoT in this study is argued to have positive influence on performance. This research argues in a similar vein that investment on IoT technologies that will complement the current ICT capabilities in a significant way. The perceived integration capability can improve the performance of supply chain, as well as firm performance. Further, these mixed methods findings reinforce several IoT related conceptual discussions (Ng et al. 2015; Ping et al. 2011) and laboratory-based study outcomes (Reaidy et al. 2015; Yan et al. 2014).

Thirdly, similar to the previous studies on ICT-enabled SCI (Li et al. 2009; Rai et al. 2006; Yu 2015), this study shows that IoT capability positively affects internal integration and external integration with suppliers and customers. Also, all three dimensions of IoT-enabled SCI improve supply chain performance. Importantly, IoT-enabled supplier and customer integration affects supply chain performance more significantly than IoT-enabled internal integration, in contrast to the general consensus (Ataseven & Nair 2017; Yu 2015). In contrast to traditional ICT (Yu 2015), IoT's conspicuous value addition is via its performance outcomes from external integration. It can be argued that IoT-enabled external integration is related at a higher significance for supply chain performance gains beyond firm boundaries due to IoT's pervasiveness and omnipresent ability. In contrast to the general consensus that firms must first establish internal integration before achieving external integration (Ataseven & Nair 2017; Huo 2012; Yu 2015; Zhao et al. 2011), all three IoT-enabled SCI dimensions related to performance. This finding suggests a unified approach to IoT deployment throughout the supply chain. The finding is consistent to IoT conceptualisation that all devices and supply chain entities integrate on this single digital platform (Borgia 2014).

Fourth, methodologically, this research contributes by providing a research framework which is analysed using structural equation modeling (SEM) of survey data. This survey-based empirical research is a first in IoT-enabled SCI studies. The study not only provides a descriptive account of IoT technologies in Australian retail supply chains, it enhances the understanding of IoT and how it helps integrating the internal and external functions through its inherent data capture and transmission capabilities. The study also provides some important empirical findings on background information such as enablers and constraints for IoT deployment, issues related to openness, standardisation and interoperability, analysis of extra data collected by IoT devices, and the drive to consolidate multiple IoT functionalities in a single device, such as the smartphone.

7.9 Practical contribution

7.9.1 Managerial implication

As IoT has already started to transform legacy ICT systems (CSIRO 2018), this study guides practitioners in many ways. First, the mixed methods results will help managers understand the emerging IoT technologies as additional firm capability to integrate the internal and external logistics functions that result in supply chain performance.

Secondly, survey results reveal the significant influence of IoT on SCI supported by qualitative findings. While the firms are at different stages of their IoT deployment, varying from 1 year to 15 years of experience, the study guides managers on investment decisions in IoT, based on the benefits realised by early adopters. So, this study guides managers towards adoption of IoT technologies. As almost all firms are a part of a supply chain (Lambert & Cooper 2000), these finding are applicable for most industry practitioners in general.

Thirdly, organisational capability theory supports IoT deployment as technological capacity building for organisations. The results show that IoT enables the SCI capability of internal and external logistics functions. While most retailers have some form of ICT technologies (e.g., barcodes, EDI, WMS etc.) as their current capability, they need to acquire, integrate, reconfigure, and release resources to upgrade with the emerging IoT technologies (e.g. RFID, sensors, handheld devices, smartphones) for connecting physical objects with the digital world for effective communication. The findings inform managers about IoT capabilities as an extension of the long established digitally-enabled SCI capability. Managers can advocate for IoT investment along these lines to complement ICT capabilities currently in place to realise new benefits. For example, the deployment of handheld smart electronic devices assists in auto-capturing crucial data around logistics, helping managers to explore data analytics. As data is at the core of digital products and services, retailers capture a huge amount of data on consumers and utilise it to give consumers what they want (SDA National 2018). The growing popularity of data analytics for effective decision-making means firms increasingly find value in data. More data means more opportunities for analytics, which in turn will provide greater intelligence for the company to operate and strategize.

Fourthly, although IoT technologies are mostly still at their nascent stage of adoption (e.g., smartphones, image-recognition), some have progressed to full deployment (e.g., GPS, barcodes, IP-camera). Retailors who do not adopt these technologies (e.g., mobile payment) will lag behind in the race and lose their competitive advantage.

A fifth managerial insight from this study is that, to capitalise on IoT-enabled SCI, managers should stretch their focus from isolated organisational management perspectives to the entire supply chain. When making IoT deployment-related decisions, managers should take a holistic supply chain perspective, rather than just focusing on the firm itself. This integrated supply chain system approach may derive greater benefits for all partners under the IoT platform, establishing a dynamic worldwide network. They should further consider linking to the existing devices of both suppliers (e.g. GPS) and customers (e.g. smartphones), mustering all digital data into one Internet-worked platform for information sharing, communication and process coordination. Managers should become conscious of collaboratively managing internal, upstream and downstream operations by making the most of IoT's global platform. They should further recognise, support and compensate their upstream partners and external service providers who adopt and invest in such IoT implementations as RFID, that may pass on more benefits further downstream. Likewise, the customer too should receive benefits for their integration efforts, for example loyality points for connecting via a smartphone app. In a self-perpetuating model such as IoT, participant value improves continuously and more members join through a snowball effect to create more value to the entire value chain (Gong & Tian 2012). Managers should consider shared benefits and shared value creation throughout the entire supply chain to encourage furthur IoT adoption to reap additional benefits.

The conceptualisation of IoT infrastructure is based on interoperable communication processes that integrate the interactions between machines and humans (Borgia 2014). Therefore, practitioners must foster more openness when it comes to IoT platforms, so that all supply partners can reap benefits. It is evident in the findings that integrating the entire supply chain under one IoT platform is what delivers better outcomes to the entire supply chain, and, in turn, the firm. Thus, improving supply chain performance together via IoT platform should be the focus with fostering interoperability, to achieve sustainable performance. Supply chain partners should consider open standards, rather than closed standards, when it comes to standardisation to foster interoperability and achieve the best out of this powerful platform. The true potential of IoT in supply chain management is when all supply chain entities are communicating and collaborating with each other under a common protocol with reduced or no human intervention. However, managers seem to currently view IoT as fragmented, untrusted and isolated when it comes to supply chain decision-making. The findings inform managers that the practices such as open standards, application interoperability and data sharing can add value to current IoT architecture. Thus, managers should consider openness, standardisation and interoperability as key enablers of true IoT platforms and true SCI.

Sixth, the research provides an IoT-enabled conceptual framework and measures, which can guide industry practitioners to achieve superior performance by evaluating IoT as a technological enabler of SCI decisions. They can develop similar models which are responsive to their particular context and supply chain strategies to improve organisational capacity through supply chain optimisation.

The unification of evolving customer needs enabled by emergent IoT technology can prompt retailers to reconsider their existing model, and brings new players in to the highly competitive market (Ramoz 2017). Bricks and mortar retailers facing tough competition from online peers should resort to disruptive technology to entice online shoppers back. The French supermarket chain Carrefour utilises the iBeacon technology across its stores which allows their customers to use their mobile phones to receive in-store promotions or to gain directions to specific goods (SDA National 2018). Continuously emerging IoT developments are launching into the market, such as sensors to help retailers monitor pedestrian traffic outside their operations to keep count of prospective customers (Gutierrez 2015), smart glasses that can be used within the warehouse as hands-free mobile computing for inventory tasks (Pauka 2017), digital-outdoor Audience in Real Time (DART), digital billboards with a discrete built-in camera which records people watching an advertisement, then builds a profile of them by deciphering age, gender, socio-economic background, and even mood, to display an tailored advertisement, and again record the response, to share the information between billboards (Butler 2018), 'Shelfie' an autonomous retail robot that combines intelligent image capturing and cloud-based data analytics solutions to report on stock levels in real-time, identify sales trends and provide insights to optimise merchandise layouts, operating as a handheld device, floor-standing robot or a drone (Gutierrez 2017). IoT is unlocking new prospects for retailers with real-time predictive analytics to help customise ordering, maintain optimally stocked shelves and minimise wastage. Applying these IoT innovations will help bricks and mortar retailers to stay competitive by providing a seamless customer experience, supported by efficiencies across supply chain operations.

Globally, behind media and entertainment, retail is the second most digitised industry (Ramoz 2017). Research by (Delloitte 2018) finds that there has been a rapid increase in digital uptake in Australia. For example, before visiting a retail store in person, 65% of the customers used a digital device before shopping for research purposes. A further 31% used a digital device while shopping to compare products increasing the conversion rate of sales by 25% (Ramoz 2017). Therefore, retailers can resort to IoT to deliver two different but seamless customer experiences by integrating their bricks and mortar and e-tail operations. The digital revolution is disrupting the retail industry at this instant, and retailers who stick to conservative methods of doing things may get left behind. They should, therefore, build their strategies to succeed today and prepare for the future challenges.

Overall, the findings may not just be important to supply chain practitioners and retailers, but also for logistics service providers, technology service providers, innovators consultants and even managers and investors in every industry to understand the value of this disruptive technology to improve day to day operations while preparing for the future.

7.9.2 Policy level implications

Disruptive technologies are given a high priority in government agendas (Lyall & Tait 2005). IoT has an infinite potential and the economic value from IoT is anticipated to generate a rapid GDP increase, therefore, enthusiasm of many governments is deeply immersed by this emerging paradigm (Borgia 2014). As a prevailing technology is gathering its momentum of everything on digital world, there are policy level strategies devised by governments all around the world to patronise this IoT revolution (Borgia 2014; Gubbi et al. 2013). Academia, research organisations, industry associations, standardisation bodies, industry stakeholders and governments are mapping a way forward to ensure a sound and healthy progress for this technological evolution (Borgia 2014; Gubbi et al. 2013).

The Australian industry report by the Department of Industry Innovation and Science (2016, p. 88) suggests that, “policy makers need stronger evidence of the link between digitally mature firms and Productivity”. The mixed methods findings confirm that Australian government investment in IoT can make a sound investment (Porkodi & Bhuvaneswari 2014). Funded initiatives worldwide to guarantee the progress of IoT were introduced a decade ago. Starting in 2009, the European Commission launched an IoT initiative to support new IoT-based applications and services; the US government started funding projects on IoT around the same time, designing a comprehensive new architecture for the next-generation Internet; in Asia, Korea, Japan and China have extensive IoT research programs (Borgia 2014).

Australia is also advancing capabilities related to IoT with the roll-out of high speed fibreoptic broadband infrastructure (Gubbi et al. 2013). The former CEO of Internet Australia articulated that allocating spectrum in a fair and equitable manner is important to ensure that the companies that are innovative in the IoT space do not get hampered by a deficit of bandwidth availability (Patton 2016). The Minister for Communications under the Turnbull Government (in 2016) pronounced that the government was committed to working together with the industry to achieve the complete potential of IoT and ensure that Australia adopted a leadership position in the region (Fifield 2016). Despite the Federal Government’s insistence on Australia’s credentials as an innovative nation, only an single active initiative was made in 2016, with the Smart Cities Plan for supporting productive, accessible, liveable cities (Department of the Prime Minister and Cabinet 2016). The Australian Government funded 52 projects under the first round of its $50 million Smart Cities program (Corner 2017).

This study can be used to gain an understanding of what IoT means, where it’s progressing, and what outcomes it can provide. It is estimated that IoT’s potential impact on the Australian economy by 2025 will be around $120 billion, despite enablers like a thriving start-up community and hindrances such as skill shortages which may affect Australia’s ability to harness IoT (Heydon & Zeichner 2015). Therefore, policy support must be provided for new business models that drive disruption from IoT technology. Also, for the progression of IoT, innovation should be embedded in the culture, starting from a young age, ensuring that the current and the future workforce are embracing technological innovations. Thus, the findings of this research may provide knowledge and encourage policy makers to be more proactive in the IoT space, make timely and progressive decisions on technology policy to eliminate the obstacles, support the IoT growth and be an IoT leader rather than a follower. The findings of the report may help advocate IoT to be elevated to a national strategy level in Australia, shadowing US, EU, China, Korea and Japan (Borgia 2014; Chang et al. 2014). This may lead to the growth and development of a local IoT industry as a commercial application.

While Germany and the US are leveraging their manufacturing potency to target industrial and manufacturing aspects of IoT, South Korea and the US again are focusing on the automotive and transport sectors, while Australia, Singapore, China and India see Smart Cities as a Government-led focus (IoT Alliance 2016). The approach of prioritising the development of IoT in sectors of natural advantage or in fields of urgent need of transformation makes sense (IoT Alliance 2016). In logistics and supply chain management, where speed is everything, the IoT is rapidly becoming the industry standard, and can be furthur utilised for greater safety, productivity and sustaibnability (Delloitte 2018). These findings make a case for policy support for industrial IoT in supply chain operations in general and the retail industry specifically. While supporting the Smart Cities initiative, the Australian government can broaden the focus to facilitate and encourage IoT implementation in not just retail operations or broad-based supply chain operation, but also in sectors such as mining, construction, agriculture, health care, manufacturing, and scientific and technical services, via its policy, technological and financial encouragements. IoT is predicted to transform all business sectors in coming years. Specifically, most firms participate in a supply chain (Lambert & Cooper 2000); thus the government could work on infrastructure improvements to facilitate such logistics tasks via IoT. Policy support must be granted in the broader context to realise global competitiveness through IoT innovations. The government and federal government agencies such as CSIRO should partner with the private sector and industry associations to drive collaboration to enable global competitiveness (Corner 2015). As an example, in 2016, IoT Alliance Australia (IoTAA 2018) and the Australian Government collaborated to launch Hypercat, an IoT interoperability standard to support the Smart Cities movement. IoT is predicted to be a disruptive force, not only in supply chain operations, but also in everyday life, so governments need to be far-sighted in their role in addressing regulatory and other enablers and constraints to help create an environment to allow the full potential of IoT to be realised in Australia. Protective legislation to mitigate data security and privacy concerns to encourage trust in the technology may encourage more users to exploit the platform.

To support the intricate connections of the IoT environment and to facilitate IoT developments in the near, medium and longer term, the Australian Communications and Media Authority (2015) suggested few priority areas including resource allocation such as spectrum, managing network security and integrity, supporting the interoperability of devices and information through standardising. The study findings also support such initiatives as priority areas for policy level responsiveness.

7.9.3 For industry associations

The findings of this study also present insights for supply chain industry associations. Most industry bodies focus on operational improvement within their industry and among members. The industry associations can facilitate sustainable competitive advantage of member organisations by educating the emerging IoT technologies and their potential benefits in their supply chain operations. With this empirical validation of how IoT can impact supply chains and in turn firm performance, the associations can encourage and support firms to devise strategies for IoT deployment, to reinforce their existing ICT infrastructure.

Some industry bodies represent IoT development globally (IoTC 2018) and locally (IoTAA 2018) for the purpose of forming partnerships and collaborating on IoT deployment strategy, best practices, and platforms with member organisations from many different sectors. IoTAA (2018) is the peak Australian IoT body with a vision to "empower industry to grow Australia's competitive advantage through IoT", to accelerate IoT innovation and adoption. The association can help empower its members to embrace the digital disruption in supply chain management. As the association seeks to activate and support collaboration across industry, government, research and communities for IoT advancement, this finding can be a validation. The study identifies IoT deployment as a strategic opportunity for economic growth as well as environmental and social benefit for firms could be a central element for potential justification of a national growth strategy across key sectors of the Australian economy, underpinned by IoT enabling technologies.

The finding that validates the effect of IoT on supply chain and logistics may be of interest to supply chain specific industry associations in Australia such as, Supply Chain and Logistics Association of Australia (SCLAA) and Logistics Association of Australia (LAA) or even global bodies such as Council of Supply Chain Management Professionals (CSCMP), Chartered Institute of Purchasing and Supply (CIPS), and the Chartered Institute of Logistics and Transport Australia (CILTA) who recognises disruptive technology, providing an early validation of IoT disrupting supply chain operations. Changing supply chain management via IoT, predictive analysis, artificial intelligence and other megatrends is very much on the agenda for these industry bodies, who organise conferences and workshops, conduct research and publish newsletters on disruptive technology in various supply chain operations.

The finding that details and encourages deployment of IoT in retail could help retail industry specific associations as well. Local bodies such as the Australian Retailers Association, National Retail Association or global groups such as Global Retail Alliance or National Retail Association that are looking for efficient technologies to improve their member operations could use the findings as an opening in validating IoT as a disruptive force that is going to strongly impact their industry. The study details the repercussions of lagging behind in this highly digitalised industry.

7.11 Chapter summary

This chapter discussed the findings of both the quantitative and qualitative phases on the hypothesised relationships within the conceptual framework, using qualitative findings to interpret, support and validate the quantitative findings. The chapter discussed the finding that IoT capability positively effects internal, supplier and customer integration to positively effects supply chain performance to impact firm performance. It also introduced literature as appropriate to justify, compare and contrast the study findings and the contribution to the literature.

The key theoretical contribution is the extention of organisational capability theory to consider IoT as a lower order capability to improve higher order organisational integration capability. Further, the study tested the heirarchical effect of IoT-enabled SCI on supply chain performance and in turn firm performance, in contrast to previous organisational capability research. The chapter also presented the potential practical implications of the findings for practitioners to encourage IoT adoption. The implications for industry associations and policy makers were also discussed.

Next chapter summarises the study and delivers a conclusion to the thesis, and the limitations of the study and future directions.

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Chapter 8
Conclusion, Limitations and Future Research Directions

IoT has emerged as an innovative technology with capabilities to improve supply chain operations to impact on organisations sustainable competitive advantage. However, the effect of IoT on SCI and in turn performance was not yet explored empirically. Therefore, this research attempted to address the research question one "*Can IoT-enabled SCI influence supply chain performance and subsequently improve firm performance?*" and the research question two "*What extent the existing IoT deployment effects SCI and in turn influences supply chain and firm performance?"* to complement the research question one, by adopting mixed research methods. The findings of this mixed methods study reveal a positive and significant relationship between IoT capability and its perceived effect on supplier, customers and internal supply chain functions of retail firms, to positively effect supply chain and firm performance respectively. While the quantitative phase collected survey data from 227 Australian retail firms and was analysed using SEM to confirm the conceptual framework, the interview-based qualitative phase centred on 13 semi-structured interviews. The interviews helped interpret and validate the quantitative findings with detailed supporting evidence. The co-existence of IoT capability in combination with ICT capability to has a significant improvement in supply chain *and* firm performance.

In contrast to available single method studies on IoT or logistics innovation, this study contributes to an small cluster of mixed method research studies in the nascent scholarly body of knowledge that explains the complex role of IoT across multitude of supply chain processes (Tu 2018). Despite both supply chain management and ICT research communities advocating for methodological diversity, the study is one of the few mixed method studies that represents either disciplines (Flint et al. 2012; Golicic & Davis 2012; Venkatesh et al. 2013), or indeed, is conducted as an interdisciplinary study.

This study contributes to the SCI literature over and above the contribution by generic ICT driven digitally-enabled SCI that is significantly associated with supply chain performance and in turn the performance of the retail firm. The findings further validate the organisational capability theory within the IoT context to prove that IoT technology alone is not the answer, but that the effective alignment of technology with intra- and inter-firm business processes is what manifests a sustainable competitive edge in firms (Rai et al. 2006). Importantly, the study extends organisational capability theory to consider IoT capability as an extension of core ICT capability to enable dynamic integration capability of firms, by empirically validating the positive effect of IoT capability on the three dimensions of SCI, using this theory as a guideline (Rai et al. 2006). The new knowledge is not restricted to veryfying IoT's effect on SCI; this study furthur contributes to the literature by empirically validating the resulting positive effect of IoT intergation on supply chains and finally firms (Ben-Daya et al. 2017; Mishra et al. 2016), to further support the theory. Many studies that addressed SCI as a multidimentional construct found that internal integration had the greatest influence on performance (Huo 2012; Yu 2015). However, this study finds that all three dimensions of IoT-enabled SCI influenced supply chain performance, with external integration demonstrating a greater significance, attesting to IoT's pervasiveness and omnipresence as a prominent value addition. The outcome differs from the general scholarly consensus that firms must first establish internal integration before focusing on external integration (Ataseven & Nair 2017), to suggests a more unified approach in IoT deployment throughout the supply chain, to corroborate with the conceptualisations of both IoT and SCI. By confirming that deploying IoT to integrate not only internal logistics but also for external partner integration affects the cost, quality, delivery and flexibility of the entire supply chain to improve firm performance, may help promote a holistic supply chain notion to achieve improved competitive financial, operational and customer performance without neglecting social and environmental outcomes.

The study not only validates such relationships, but also details existing IoT technologies in Australian retail supply chains, how they are deployed in internal and external firm processes to strengthen SCI and the resulting performance outcomes in supply chains and firms. IoT's additional capabilities in real-time visibility, auto-capture and inter- and intra-firm communication and collaboration are perceived to be accountable for this performance improvement in the current supply chain context. The study also discusses some contextual information such as enablers and constraints, issues, implication of data analysis and interoperability issues to offer a better understanding on the role and the potential of IoT within an intricate supply chain environment for organisations to achieve a competitive edge.

The study findings may inspire industry practitioners to consider IoT deployment to strengthen their existing ICT architecture. Additionally, the findings dismiss the traditional view of a direct relationship between ICT implementation and performance. Rather, IoT deployment can be understood as being deeply rooted in business processes for better outcomes for firms, financially, socially and environmentally, to deliver the broader embodiment of IoT disruption. This study outlines practical strategies for industry practitioners to manage their business processes in this transition to the era of IoT. The findings advise managers that, when it comes to IoT-enabled SCI, they should broaden their emphasis from their own firm to the entire supply chain, to keep internal and external focus balanced, given that all three aspects of IoT-enabled integration affect supply chain performance equally, due to IoT's pervasive ability. Therefore, it is recommended that managers take a holistic supply chain perspective, in IoT investment decisions for greater benefits for all partners. The findings encourage open standards, application interoperability and data sharing to achieve envisioned IoT platforms, therefore envisioned SCI, for greater performance. The key recommendation from this research is that managers should seek to develop IoT-enabled SCI capability to achieve sustainable competitive advantage in an increasingly volatile environment. They should consider an integrated approach to the entire supply chain system to derive greater benefits to all partners.

The study also contributes to policy making by providing evidence that the investment in IoT is a sound public investment. It is recommended that national strategies to speed up IoT deployment be pursued and funding be allocated for further IoT research. The findings may help advocate for industrial IoT to be lifted to the national strategy level in Australian, shadowing the current Smart City initiative. The study may present insights for industry associations to encourage operational improvement within their industry and between members to achieve sustainable competitive advantage via IoT integration, through this early validation of IoT disruption in supply chain operations, and the ramifications of ignorance in this highly digitalised industry. The finding may encourage innovation to broaden the IoT technology development, particularly in the industry space and also may further validate the work of global IoT initiatives and not-for-profit standardisation bodies to reinforce their efforts.

Overall, the study presents valuable implications for supply chain management research, practice and policy making to demonstrate the importance of not just IoT deployment, but also proper alignment of IoT into their supply chain processes to add value to all partners to deliver sustainable competitive advantage for firms.

IoT is a self-perpetuating model in which the stakeholder value improves continuously. When more members join through a snowball effect, it can create more value to the entire supply chain and all partners within that chain, especially the customer. When the technology progresses, and more communities participate, IoT has the potential to mature as an omnipresent dynamic global network possessing autonomous intelligence to assist individuals, industries, society and the environment.

8.1 Limitations and future research directions

There are some limitations of this study that offer future research opportunities. First, in a SCI context, contingency theory suggests that the aspects of SCI should be aligned to achieve the best performance (Flynn et al. 2010). The theory recommends that organisations should shape their strategies and processes in response to internal operational characteristics and external environmental conditions (Wong et al. 2011b). Therefore, the internal operational characteristics and external environmental conditions may moderate IoT-enabled supply chain integrative drivers, as well as performance outcomes. Prior studies have examined the mediating effect of internal operational characteristics and external environmental conditions on integrating information flows and performance (Wong et al. 2011a). Wong et al. (2011a) categorise external environmental conditions as environmental munificence (the extent to which a business environment can sustain growth) and environmental uncertainty (an organisation's inability to predict outcomes of their decisions), and internal operational characteristics as product type and product complexity. Therefore, environmental munificence and environmental uncertainty have a moderating effect on IoT-enabled SCI on supply chain performance. Testing this moderating effect is proposed as a future research agenda.

Second, the framework was tested with a sample size of 227 cases. Although the sample size was adequate for SEM analysis, it was inadequate for inter-group analysis to see how a retail sector is significantly performing in comparison to other retail sectors in terms of IoT adoption. The interview data (n=13) provided some representation in inter-group analysis of IoT forms. However, it did not make sense to undertake this analysis in a mixed method study as it would not help to support the survey findings. Therefore, future research may like to undertake a retail sector-based analysis. Potential findings may allow more granulated details of how IoT affects each retail sector and if and how each is different from the other.

Third, although IoT is discussed as technologies to seamlessly track and trace entities throughout the supply chain from 'farm to plate' to recycling (Kiritsis 2011; Lianguang 2014) with its potential for optimal integration (Moreno et al. 2014), the framework used only the perception of focal retailers. Therefore, extending this framework to all partners such as growers, manufactures, wholesalers, logistics service providers and customers in a quantitative investigation could reveal more information on IoT technologies and the way these can help capture data in a networked supply chain for better decision-making.

Fourth, even though two environmental sustainability items and two social sustainability items were included in firm performance measures, that is not enough to emphasise on firm sustainability measured on environment, social and economic criteria. However, the interview findings suggest that the managers perceive IoT integration in their supply chain to enable triple bottom lines of firm sustainability. Therefore, a future study can include an instrument designed with a more balanced approach to triple bottom lines (economic, environmental and social). This could mean a more equalised number of firm performance measures or extending the current model to having three exogenous constructs of economic, environmental and social performance, representing endogenous firm performance construct which may reveal further on this theme.

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Appendices

Appendix A: Ethics approval

Dear DR HIMANSHU SHEE,

Your ethics application has been formally reviewed and finalised.

» Application ID: HRE16-169

» Chief Investigator: DR HIMANSHU SHEE

» Other Investigators: DR SHAH JAHAN MIAH, MR Tharaka De Vass Gunawardena

» Application Title: "Internet of Things" enabled supply chain integration and performance: Australian retail industry perspectives

» Form Version: 13-07

The application has been accepted and deemed to meet the requirements of the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007)' by the Victoria University Human Research Ethics Committee. Approval has been granted for two (2) years from the approval date; 26/07/2016.

Continued approval of this research project by the Victoria University Human Research Ethics Committee (VUHREC) is conditional upon the provision of a report within 12 months of the above approval date or upon the completion of the project (if earlier). A report proforma may be downloaded from the Office for Research website at: http://research.vu.edu.au/hrec.php.

Please note that the Human Research Ethics Committee must be informed of the following: any changes to the approved research protocol, project timelines, any serious events or adverse and/or unforeseen events that may affect continued ethical acceptability of the project. In these unlikely events, researchers must immediately cease all data collection until the Committee has approved the changes. Researchers are also reminded of the need to notify the approving HREC of changes to personnel in research projects via a request for a minor amendment. It should also be noted that it is the Chief Investigators' responsibility to ensure the research project is conducted in line with the recommendations outlined in the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007).'

On behalf of the Committee, I wish you all the best for the conduct of the project.

Secretary, Human Research Ethics Committee

Phone: 9919 4781 or 9919 4461

Email: researchethics@vu.edu.au

Appendix B: Invitation and information to survey participants

INFORMATION TO SURVEY PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

You are invited to participate in a research project entitled "Internet of Things" enabled supply chain integration and performance: Australian retail industry perspectives.

This project is being conducted by a student researcher Tharaka de Vass Gunawardena as part of a PhD study at Victoria University under the supervision of Dr Himanshu Shee from the College of Business.

Project explanation

This study examines the contribution of 'Internet of Things' (IoT) capabilities in retail supply chains to the integration of suppliers, internal functions and customers, that in turn would influence supply chain performance. Internet of Things (IoT) is an Internet and WiFi-connected devices to seamlessly integrate physical objects along a supply chain. IoT can be simply explained as an extension of traditional information and communication technology or a transition from internetworked computers to internetworked objects. Its ability to capture deeper and accurate real-time information helps to improving supply chain performance. While Australian retail organisations substantially employ "Internet of things (IoT)" technologies in their supply chain activities, little is known about the effect of IoT applications on performance gains. Australian retailer industry will benefit from the fact that IoT application and related investment will bring in a significant improvement in supply chain operations.

What will I be asked to do?

You are invited to contribute in this research project. You are requested to voluntarily participate in a survey that should take approximately 20 minutes to complete. Most questions simply require you to choose an answer from a list of options and then tick the radio button relevant response that corresponds to your choice. In some unique instances we require you to type certain facts/short single line answers.

What will I gain from participating?

You can obtain an electronic copy of the customised research report from this research, if you choose to provide your email address. Subsequently, the potential finding may provide managers with insight into the potential of IoT capabilities in integrating the supply chain partners for operational efficiency via information exchange. Such integration may further improve supply chain performance by improving cost, quality, delivery and operational flexibility in the retail sector.

How will the information I give be used?

The survey data will be analysed using Structural Equation Modeling to validate the relationship between the capability of IoT, supply chain integration and its effect on performance.
The interview data will be used to interpret and support the survey findings.

What are the potential risks of participating in this project?

Loss of your time and survey fatigue is considered as the key costs to the participants. Most of the questions will be on IoT as implementation in mainstream transactions to improving supply chain operations. It is not anticipated that this information is potentially harmful or confidential. However, the survey participants are advised and encouraged to gain approval from their hierarchy.

How will this project be conducted?

Mixed methods will be employed in this study via a survey of the Australian retail industry as well as a few select case companies. The survey results will be statistically analysed to measure the strength of study hypothesis. The interview data will be analysed using qualitative data analysis methods to be used to interpret and support the survey findings.

Who is conducting the study?

College of Business, Victoria University, 300 Flinders street, Melbourne, Victoria 3000

Chief Investigator Dr. Himanshu Shee on (03) 9919 4077 or Alternatively, at Himanshu.Shee@vu.edu.au.

Student Researcher Tharaka de Vass Gunawardena on 0410771565, alternatively, at tharaka.devassgunawardena@live.vu.edu.au.

Any queries about your participation in this project may be directed to the Chief Investigator listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

Appendix C: Invitation and information for interview participants

INFORMATION TO INTERVIEW PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

You are invited to participate in a research project entitled "Internet of Things" enabled supply chain integration and performance: Australian retail industry perspectives.

This project is being conducted by a student researcher Tharaka de Vass Gunawardena as part of a PhD study at Victoria University under the supervision of Dr Himanshu Shee from the College of Business.

Project explanation

This study examines the contribution of 'Internet of Things' (IoT) capabilities in retail supply chains to the integration of suppliers, internal functions and customers, that in turn would influence supply chain performance. Internet of Things (IoT) is an Internet and WiFi-connected devices to seamlessly integrate physical objects along a supply chain. IoT can be simply explained as an extension of traditional information and communication technology or a transition from internetworked computers to internetworked objects. Its ability to capture deeper and accurate real-time information helps to improving supply chain performance. While Australian retail organisations substantially employ "Internet of things (IoT)" technologies in their supply chain activities, little is known about the effect of IoT applications on performance gains. Australian retailer industry will benefit from the fact that IoT application and related investment will bring in a significant improvement in supply chain operations.

What will I be asked to do?

You are invited to contribute in this research project. You are requested to voluntarily participate in an interview that should take approximately an hour. The interviews will be audio recorded with your permission. The organisations will be given the option to remain de-identified and referred to using a pseudonym and all interviewees names will also be de-identified to maintain confidentiality.

What will I gain from participating?

You can obtain an electronic copy of the customised research report from this research, if you choose to provide your email address. Subsequently, the potential finding may provide managers with insight into the potential of IoT capabilities in integrating the supply chain partners for operational efficiency via information exchange. Such integration may further improve supply chain performance by improving cost, quality, delivery and operational flexibility in the retail sector.

How will the information I give be used?

The survey data will be analysed using Structural Equation Modeling to validate the relationship between the capability of IoT, supply chain integration and its effect on performance.
The interview data will be used to interpret and support the survey findings.

What are the potential risks of participating in this project?

Loss of your time and survey fatigue is considered as the key costs to the participants. Most of the questions will be on IoT as implementation in mainstream transactions to improving supply chain operations. It is not anticipated that this information is potentially harmful or confidential. Your organisation has consented to participate. However, the interview participants are advised and encouraged to gain approval from their hierarchy.

How will this project be conducted?

Mixed methods will be employed in this study via a survey of the Australian retail industry as well as a few select case companies. The survey results will be statistically analysed to measure the strength of study hypothesis.
The interview data will be analysed using qualitative data analysis methods to be used to interpret and support the survey findings.

Who is conducting the study?

College of Business, Victoria University, 300 Flinders street, Melbourne, Victoria 3000

Chief Investigator Dr, Himanshu Shee on (03) 9919 4077 or alternatively, at Himanshu.Shee@vu.edu.au.

Student Researcher Tharaka de Vass Gunawardena on 0410771565 or alternatively, at tharaka.devassgunawardena@live.vu.edu.au.

Any queries about your participation in this project may be directed to the Chief Investigator listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

Appendix D: Recruitment Flier

IoT in Supply Chains

Internet of things (IoT) is identified as one of the most powerful technological advancements with the potential to connect people and things (objects) anytime, anywhere using any Internet network and service. Many technology leaders such as Accenture, Gartner, PWC has discussed the improtance of IoT for Suppy Chains. While retail organisations substantially employ "Internet of things (IoT)" technologies in their supply chain activities, little is known about the effect of IoT applications on performance gains. This study conducted by Victoria University examines the contribution of 'Internet of Things' (IoT) capabilities in Australian retail supply chains.

You are requested to voluntarily participate in an anonymise online survey that should take approximately 20 minutes to complete. Participation can help you reflect on your own organization's performance. The potential finding may guide industry practitioners with insight into the potential of IoT capabilities in integrating the supply chain processes for performance gains.

Please note the information to survey participants and consent information are attached.

Please click on the below link to take the survey,
IoT in Supply Chains Or https://vuau.qualtrics.com/SE/?SID=SV_6tyBu9OZ0QhCjhH

Thank you.
Regards,
Tharaka de Vass Gunawardena

Appendix E: Consent information for survey participants

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

CONSENT FORM FOR SURVEY PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate in this study that examines “Internet of Things” enabled supply chain integration and performance: Australian retail industry perspectives.

What is IoT, and why is integration important?

Internet of things (IoT) is identified as one of the most powerful technological advancements with the potential to connect people and things (objects) anytime, anywhere using any internet network and service. The data produced by IoT helps to foster information sharing among individuals, organisations, industries, and society. With increasing industry applications, IoT has the potential to capture additional data flowing among supply chain entities, processes, equipment and people, and transfer it in real-time. Information sharing and collaborative management are drivers of supply chain integration. IoT application is viewed as an extension of current ICT with the potential to address the existing information exchange gap in supply chains thereby improving the chain performance.

Why another survey?

While Australian retail organisations substantially employ IoT technologies in their supply chain activities, little is known about the effect of IoT on performance gains. The results of this study, conducted by Tharaka de Vass Gunawardena, a Ph.D. student at Victoria University, will be communicated to business and used to highlight the potential of IoT applications in supply chains, and help management decisions in adopting IoT for supplier and customer integration into the core internal functions. The potential finding may further deliver benefits for consumers and retailers alike by shedding light on such novel technology innovation to help improve retail productivity.

Who should fill in this questionnaire?

This survey is intended to be completed by a manager overseeing supply chain operations within your retail organisation. If you are unable to answer any of the questions, we would appreciate you passing the questionnaire on to a suitable potential respondent within your organisation.

Participation in this survey is voluntary, the results will be anonymised meaning your organization will not be identified, and only the researchers involved in the project will have access to the information in this survey. All information will be stored in compliance with Victoria University data management guidelines.

ALL INFORMATION WILL BE TREATED IN THE STRICTEST CONFIDENCE

What do you have to do?

You are invited to fill in this survey that should take approximately 20 minutes to complete. Most questions simply require you to choose an answer from a list of options and then tick the relevant response. In some unique instances we require you to provide short answers of no more than a single line. We appreciate that these details may not be easily recalled, and in such cases, we ask that you provide us with your best guess.

What are the risks and benefits of participating?

Benefits outweigh the risk of participation. Survey fatigue and loss of time are the key risks for the participants of this research. In contrast Australian retail industry can benefit from the fact that extension from Internet-connected computers to Internet-connected devices can further strengthen supply chain information exchange mechanism to improving chain performance. Participation can help you reflect on your own organization’s performance. The potential finding may guide industry practitioners with insight into the potential of IoT capabilities in integrating the supply chain processes for performance gains. The study can also contribute to policy changes favouring a decision on a new investment in IoT as emerging technology application. This may further deliver benefits for consumers and retailers alike by shedding light on such novel technology innovation to help improve retail productivity.

Any questions?

For more information, please contact the Chief Investigator Dr. Himanshu Shee on (03) 9919 4077 or alternatively, at Himanshu.Shee@vu.edu.au or the Student Researcher Tharaka de Vass Gunawardena on 0410771565 or alternatively, at tharaka.devassgunawardena@live.vu.edu.au.

This project has received clearance from the Victoria University Human Research Ethics Committee. If you have any concerns about the conduct of this project, please contact the Secretary, Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001, phone (03) 9919 4781/4461 or email: researchethics@vu.edu.

Obtaining copies of research related to this project

If you would like to receive an electronic copy the customised research report from this research, please provide your email in the space provided at the end of the survey.

By clicking proceed with the survey below, completing and submitting your response, your consent to participate is assumed. That is, you have understood the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to you by: Tharaka de Vass Gunawardena. However, you can withdraw from this study at any time and that this withdrawal will not jeopardise you in any way.

Appendix F: Survey questionnaire

IoT in Supply Chains

"Internet of things" enabled supply chain integration and performance: Australian retail industry perspectives

You are invited to participate in this study that examines how 'Internet of Things' (IoT) capabilities in retail supply chains contribute to the integration of suppliers, internal functions and customers, that in turn would influence supply chain performance. What is IoT, and how does it help in integration? Internet of things (IoT) is identified as one of the most powerful technological advancements with the potential to connect people and things (objects) anytime from anywhere using Internet network and services. IoT-captured data helps to foster information sharing among individuals, organisations, industries, and society. With increasing industry applications, IoT has the potential to capture additional data flowing among supply chain entities, processes, equipment and people, and transfer it in real-time. IoT application is viewed as an extension of current ICT with the potential to address the existing information exchange gap in supply chains thereby improving the chain performance. Information sharing and collaborative management are drivers of supply chain integration. Contemporary retail supply chains not only requires supply chain members (eg. suppliers, manufacturers, warehouses, customers) to be integrated, but also to integrate various external functions, such as transportation, distribution and storage of goods.

Why another survey?

While Australian retail organisations substantially employ IoT technologies in their supply chain activities, little is known about the effect of IoT on integration and performance. The results of this study, conducted by Tharaka de Vass Gunawardena, a Ph.D. student at Victoria University, will be communicated to business and used to highlight the potential of IoT applications in supply chains, and help management decisions in adopting IoT for supplier and customer integration into the core internal functions. The findings may further deliver benefits for consumers and retailers by improving retail productivity.

Why were you contacted and how we contacted you.

This survey is intended to be completed by a manager overseeing supply chain operations within your retail organisation. We obtained your email contact details through the membership directories of leading industry association in Australia for supply chain management/logistics/retail. If you are unable to answer the questions, we would appreciate you passing the questionnaire on to a suitable potential respondent within your organisation. Participation in this survey is voluntary, the results will be anonymised meaning your organization will not be identified, and only the researchers involved in the project will have access to the information in this survey. All information will be stored in compliance with Victoria University data management guidelines.

ALL INFORMATION WILL BE TREATED IN THE STRICTEST CONFIDENCE

What do you have to do?

You are invited to fill in this survey. It should take approximately 20 minutes to complete. Most questions simply require you to choose an answer from a list of options and then tick the relevant response. In some unique instances we require you to provide short answers of no more than a single line. We appreciate that these details may not be easily recalled, and in such cases, we ask that you provide us with your best guess. What are the risks and benefits of participating? The loss of time is the key risk for participating in this research. However, participation can help you reflect on your own organisation's performance. The potential finding provide insights that may guide Australian retail industry practitioners into the adoption and strengthening potential of IoT capabilities in integrating the supply chain processes for performance improvement. The study can also contribute to policy changes favouring a decision on a new investment in IoT as emerging technology application. This may further deliver benefits for consumers and retailers alike by shedding light on such novel technology innovation to help improve retail productivity.

Any questions?

For more information, please contact the Chief Investigator Dr. Himanshu Shee on (03) 9919 4077 or at Himanshu.Shee@vu.edu.au or the student researcher Tharaka de Vass Gunawardena on 0410771565 or at tharaka.devassgunawardena@live.vu.edu.au. This project has received clearance from the Victoria University Human Research Ethics Committee. If you have any concerns about the conduct of this project, please contact the Secretary, Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001, phone (03) 9919 4781/4461 or email: researchethics@vu.edu.au .

Obtaining copies of research related to this project

If you would like to receive a summary and key finding of this study, please provide your email in the space provided at the end of the survey.

Consenting to participate

By clicking proceed with the survey below, completing and submitting your response, your consent to participate is assumed. That is, you have understood the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research. However, you can withdraw from this study at any time and that this withdrawal will not jeopardise you in any way.

Q1. Please indicate the geographic scope of your supply chain network (inclusive of suppliers and customers): (Please pick one answer)

- ❍ Local (only within Australia). (1)
- ❍ Regional (only within Australia and Asia pacific). (2)
- ❍ Worldwide. (3)

[Message: IoT can be simply explained as an extension of traditional Information and Communication Technology or a transition from Internet connected network of computers, to Internet connected network of various objects (listed below). IoT has the potential to connect people and things (objects) anytime, anywhere using any Internet network and service. The data produced by IoT helps to foster information sharing among individuals, organisations, industries, and society. IoT has the potential to capture additional data flowing among supply chain entities, processes, equipment and people, and transfer it in real-time. This ubiquitous Internet connected devices can seamlessly integrate physical objects in supply chain operations. Your supply chain operations may not only include the relationships and linkages between the suppliers, internal cross functional processes and customers but also include in-house/external logistics service providers involved in transportation, distribution and storage of goods]

Q2. What IoT forms are currently in use in your supply chain operations, or do you intend to adopt in your supply chain operations in the future? When did your supply chain first implement or plan to adopt each form of IoT? (Please specify for each item below. Please answer all questions).

Adopted over 3 years ago (1), Adopted less than 3 years ago (2), In the process of implementing (3), Plan to adopt within next 3 years (4), No plans to adopt in the next 3 years (5).

	1	2	3	4	5
RFID related tagging and tracking (1)	❍	❍	❍	❍	❍
Internet based barcode technology (2)	❍	❍	❍	❍	❍
GPS based location awareness (3)	❍	❍	❍	❍	❍
Internet based sensors and scanners (4)	❍	❍	❍	❍	❍
Handheld/palm-held tablets/smart-devices (5)	❍	❍	❍	❍	❍
Smartphones and mobile apps (6)	❍	❍	❍	❍	❍
Internet based appliances/equipment/beacons (7)	❍	❍	❍	❍	❍
Internet based wearable devices (8)	❍	❍	❍	❍	❍
Internet based security and surveillance (9)	❍	❍	❍	❍	❍
Internet based transportation devices (10)	❍	❍	❍	❍	❍
Internet based logistic equipment (11)	❍	❍	❍	❍	❍
Internet based immobile/fixed devices (12)	❍	❍	❍	❍	❍
Real-time streaming analytics via IoT data (13)	❍	❍	❍	❍	❍
Data analytics using IoT data (14)	❍	❍	❍	❍	❍
Autonomous reporting/alert (15)	❍	❍	❍	❍	❍
Autonomous decision-making/action/reaction (16)	❍	❍	❍	❍	❍
Image recognition via IoT (17)	❍	❍	❍	❍	❍
Others 1 (please specify) (18)	❍	❍	❍	❍	❍
Others 2 (please specify) (19)	❍	❍	❍	❍	❍

Q3. Which of the following reasons influence the decision to adopt IoT in your organisations supply chain? (You can select multiple options):

- ❑ Improve overall business performance (1)
- ❑ Improve supply chain management performance (2)
- ❑ Competitive pressure (3)
- ❑ Enhance decision making via data capture (4)
- ❑ Increase sales via analytics (5)
- ❑ Customer preference/improve customer experience (6)
- ❑ Supplier requirement (7)
- ❑ Industry standard (8)
- ❑ Gain more information/data to diagnose problems (9)
- ❑ Cost reduction via operational efficiency (10)
- ❑ To be a technology leader (11)
- ❑ Legislative requirement (12)
- ❑ Other (please specify) (13) ____________________

Q4. IoT has the capability in our supply chain operations to, (Please specify for each item below. Please answer all questions).

Strongly agree (7), Agree (6), Somewhat agree (5), Neither agree nor disagree (4), Somewhat disagree (3), Disagree (2), Strongly disagree (1).

	7	6	5	4	3	2	1
provide individual item level identification (eg. tagging with RFID, barcode, QR code). (1)	❍	❍	❍	❍	❍	❍	❍
provide unit level (product group/pallet) identification (eg. tagging with RFID, barcode, QR code). (2)	❍	❍	❍	❍	❍	❍	❍
monitor, track and trace supply chain entities and people through auto-captured data (eg. tracking with barcode, QR code, RFID, GPS, smartphones). (3)	❍	❍	❍	❍	❍	❍	❍
measure supply chain activities, processes and its environmental conditions (eg. temperature/environmental monitoring, speed, process mapping, customer shopping behavior). (4)	❍	❍	❍	❍	❍	❍	❍
help control supply chain processes remotely (eg. remote monitoring, surveillance, alerts, auto reporting). (5)	❍	❍	❍	❍	❍	❍	❍
make autonomous supply chain decisions (eg. auto ordering, temperature control). (6)	❍	❍	❍	❍	❍	❍	❍
provide real-time information to optimize supply chain activities (eg. route optimization, reporting, alert). (7)	❍	❍	❍	❍	❍	❍	❍
provide real-time intelligence of supply chain operations (eg. real-time processing, real-time streaming analytics). (8)	❍	❍	❍	❍	❍	❍	❍
provide large volumes and variety of data to apply data analytics for tactical and strategic decision making. (9)	❍	❍	❍	❍	❍	❍	❍
strengthen inter and intra organizational information sharing within the supply chain. (10)	❍	❍	❍	❍	❍	❍	❍
facilitate inter and intra organizational decision making within the supply chain. (11)	❍	❍	❍	❍	❍	❍	❍
strengthen communication and coordination between operators. (12)	❍	❍	❍	❍	❍	❍	❍

How has your supply chain processes improved over the last three years, compared with that of your main competitor(s), in the following chosen areas?

Q5. We have been able to improve the business processes with our suppliers to, (Please specify for each item below. Please answer all questions).

Strongly agree (7), Agree (6), Somewhat agree (5), Neither agree nor disagree (4), Somewhat disagree (3), Disagree (2), Strongly disagree (1).

	7	6	5	4	3	2	1
improve information exchange with our suppliers. (1)	❍	❍	❍	❍	❍	❍	❍
establish a quick ordering of inventory from our suppliers. (2)	❍	❍	❍	❍	❍	❍	❍
accurately plan and adopt the procurement process in collaboration with our suppliers. (3)	❍	❍	❍	❍	❍	❍	❍
stabilize procurement with our suppliers. (4)	❍	❍	❍	❍	❍	❍	❍
share real-time demand forecasts with our suppliers. (5)	❍	❍	❍	❍	❍	❍	❍
improve strategic partnerships with our suppliers. (6)	❍	❍	❍	❍	❍	❍	❍
help our suppliers improve their processes to better meet our needs. (7)	❍	❍	❍	❍	❍	❍	❍
improve the account payable processes for suppliers. (8)	❍	❍	❍	❍	❍	❍	❍
improve the transport/logistics processes for logistics partners to deliver orders just in time. (9)	❍	❍	❍	❍	❍	❍	❍
improve our receiving processes for delivered goods. (10)	❍	❍	❍	❍	❍	❍	❍

Q6. We have been able to improve our internal logistics processes (functional areas within the organisation) to, (Please specify for each item below. Please answer all questions)

Strongly agree (7), Agree (6), Somewhat agree (5), Neither agree nor disagree (4), Somewhat disagree (3), Disagree (2), Strongly disagree (1).

	7	6	5	4	3	2	1
improve the integration of data among internal functions. (1)	❍	❍	❍	❍	❍	❍	❍
improve real-time communication and linkage among all internal functions. (2)	❍	❍	❍	❍	❍	❍	❍
accurately plan and adopt internal processes in collaboration with cross functional teams. (3)	❍	❍	❍	❍	❍	❍	❍
make and adopt demand forecasts in collaboration with cross functional teams. (4)	❍	❍	❍	❍	❍	❍	❍
improve inventory management in collaboration with cross functional teams. (5)	❍	❍	❍	❍	❍	❍	❍
improve real-time searching of the inventory levels. (6)	❍	❍	❍	❍	❍	❍	❍
improve real-time searching of logistics-related operating data. (7)	❍	❍	❍	❍	❍	❍	❍
employ cross functional teams in process improvement. (8)	❍	❍	❍	❍	❍	❍	❍
improve replenishment of shop floor shelves. (9)	❍	❍	❍	❍	❍	❍	❍
reduce stock outs in the shop floor shelves. (10)	❍	❍	❍	❍	❍	❍	❍

Q7. Australia is a dream tourist destination because of the : (Please specify for each item below. Please answer all questions).

Strongly agree (7), Agree (6), Somewhat agree (5), Neither agree nor disagree (4), Somewhat disagree (3), Disagree (2), Strongly disagree (1).

	7	6	5	4	3	2	1
attractions (eg. beaches, aboriginal arts & culture, national parks, casinos, pubs). (1)	❍	❍	❍	❍	❍	❍	❍
atmosphere and environment (eg. friendliness of local people, weather and climate, clean beaches, clean streets, safety). (2)	❍	❍	❍	❍	❍	❍	❍
shopping (eg. variety of goods, service quality, price, product quality). (3)	❍	❍	❍	❍	❍	❍	❍
restaurant/food outlets (eg. service quality, variety of choice, value for money). (4)	❍	❍	❍	❍	❍	❍	❍

Q8. We have been able to improve the business processes with our customers to, (Please specify for each item below. Please answer all questions).

Strongly agree (7), Agree (6), Somewhat agree (5), Neither agree nor disagree (4), Somewhat disagree (3), Disagree (2), Strongly disagree (1).

	7	6	5	4	3	2	1
improve the strength of linkages with our customers. (1)	❍	❍	❍	❍	❍	❍	❍
improve regular contacts with our customers. (2)	❍	❍	❍	❍	❍	❍	❍
improve communication with our customers on products and promotions. (3)	❍	❍	❍	❍	❍	❍	❍
make and adopt demand forecasts with real-time understanding of market trends. (4)	❍	❍	❍	❍	❍	❍	❍
improve the customer shopping experience/time/ordering/customizing processes. (5)	❍	❍	❍	❍	❍	❍	❍
accurately plan and adopt the checkout/dispatch/delivery processes through better understanding of market trends. (6)	❍	❍	❍	❍	❍	❍	❍
improve the check-out/dispatch/delivery process of goods. (7)	❍	❍	❍	❍	❍	❍	❍
improve and simplify the payment receivable process from our customers. (8)	❍	❍	❍	❍	❍	❍	❍
improve our customer feedback process. (9)	❍	❍	❍	❍	❍	❍	❍

How has your current performance improved over the last three years, compared with that of your main competitor(s), in the following chosen areas?

Q9. We have been able to develop our supply chain processes to, (Please specify for each item below. Please answer all questions).

Strongly agree (7), Agree (6), Somewhat agree (5), Neither agree nor disagree (4), Somewhat disagree (3), Disagree (2), Strongly disagree (1).

	7	6	5	4	3	2	1
improve product quality. (1)	❍	❍	❍	❍	❍	❍	❍
improve supply chain delivery reliability. (2)	❍	❍	❍	❍	❍	❍	❍
improve fill rates. (3)	❍	❍	❍	❍	❍	❍	❍
improve perfect order fulfillment (deliveries with no errors). (4)	❍	❍	❍	❍	❍	❍	❍
improve supply chain flexibility (react to product changes, volume, mix). (5)	❍	❍	❍	❍	❍	❍	❍
reduce the cash-to-cash cycle time. (6)	❍	❍	❍	❍	❍	❍	❍
reduce the total supply chain management cost. (7)	❍	❍	❍	❍	❍	❍	❍
reduce the cost of goods sold. (8)	❍	❍	❍	❍	❍	❍	❍
improve value-added productivity (sales per employee). (9)	❍	❍	❍	❍	❍	❍	❍

Q10. We been able to develop our organisational operations to, (Please specify for each item below. Please answer all questions).

Strongly agree (7), Agree (6), Somewhat agree (5), Neither agree nor disagree (4), Somewhat disagree (3), Disagree (2), Strongly disagree (1).

	7	6	5	4	3	2	1
Improve the product delivery cycle time. (1)	❍	❍	❍	❍	❍	❍	❍
improve productivity (e.g. assets, operating costs, labor costs). (2)	❍	❍	❍	❍	❍	❍	❍
improve sales of existing products. (3)	❍	❍	❍	❍	❍	❍	❍
find new revenue streams (e.g. new products, new markets). (4)	❍	❍	❍	❍	❍	❍	❍
build strong and continuous bonds with customers. (5)	❍	❍	❍	❍	❍	❍	❍
gain precise knowledge of customer buying patterns. (6)	❍	❍	❍	❍	❍	❍	❍
improve customer satisfaction. (7)	❍	❍	❍	❍	❍	❍	❍
improve employee satisfaction. (8)	❍	❍	❍	❍	❍	❍	❍
improve employee health and safety. (9)	❍	❍	❍	❍	❍	❍	❍
reduce energy use. (10)	❍	❍	❍	❍	❍	❍	❍
improve return/re-use/recycle. (11)	❍	❍	❍	❍	❍	❍	❍

Q11. How many employees does your organization have? (Please pick one answer)

❍ less than 20 (1)
❍ 20-199 (2)
❍ 200 and above (3)

Q12. Please indicate your organizations retail model: (Please pick one answer)

- ❍ Traditional store based walk-in model (bricks and mortar) (1)
- ❍ Online sales model (e-tail) (2)
- ❍ Multi-channel sales model (both) (3)
- ❍ Other (please specify) (4) ____________________

Q13. Please indicate the nature of your retail organisation. (Please pick one answer)

- ❍ Restaurant, café, takeaway (1)
- ❍ Supermarkets, grocery (2)
- ❍ Household goods (e.g. hardware, furniture) (3)
- ❍ Clothing, footwear and personal accessories (4)
- ❍ Electrical, electronic, computer (5)
- ❍ Pharmaceutical, cosmetic, toiletry (6)
- ❍ Motor vehicles & parts (7)
- ❍ Fuel and convenience stores (8)
- ❍ Department stores (9)
- ❍ Other (please specify) (10) ____________________

Q14. Please indicate for how long you have been working in this organisation. (Please pick one answer)

- ❍ less than 1 year (1)
- ❍ 2 to 4 years (2)
- ❍ 5 to 6 years (3)
- ❍ 7 to 8 years (4)
- ❍ 9 to 10 years (5)
- ❍ over 11 years (6)

Q15. Please indicate your job designation: (Please pick one answer)

- ❍ CEO/Chairmen/MD//Director/General manager (1)
- ❍ Operations/Supply Chain/Logistics manager (2)
- ❍ Middle management (3)
- ❍ IT manager (4)
- ❍ Staff (5)
- ❍ Others (please specify) (6) ____________________

Q16. Please indicate your level of involvement in strategic decision making with respect to supply chain operations in your organisation. (Please pick one answer)

- I am a key decision maker in this area (1)
- To a considerable extent (2)
- To a moderate extent (3)
- To a slight extent (4)

Thank you for participating on this survey. Please click "submit" button below to submit your answers. Are you interested in participating further in this study? The next research phase will involve investigating a few case companies on their use of IoT in supply chains. Participating in the next phase can help your organization reflect on its' capabilities in IoT-enabled supply chain integration, and understand how IoT influences supply chain performance. If you are interested in participating, a number of selected people from your supply chain operations will be interviewed to gain their insights, with the consent of both the organisation and the participant. If you would like to learn more about how your organisation can be involved in the next research phase, please provide the details of the appropriate contact person.

Contact person: (1)

Designation: (2)

Email (3)

If you want a customised report sent to you after the data collection is finalised, please provide your email address below.

Appendix G: Consent form for interview participants

VICTORIA UNIVERSITY
MELBOURNE AUSTRALIA

CONSENT FORM FOR INTERVIEW PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite you and your organization to be a part of a study into "Internet of Things" enabled supply chain integration and performance: Australian retail industry perspectives

What is IoT, and why is integration important?

Internet of things (IoT) is identified as one of the most powerful technological advancements with the potential to connect people and things (objects) anytime, anywhere using any internet network and service. The data produced by IoT helps to foster information sharing among individuals, organisations, industries, and society. With increasing industry applications, IoT has the potential to capture additional data flowing among supply chain entities, processes, equipment and people, and transfer it in real-time. Information sharing and collaborative management are drivers of supply chain integration. IoT application is viewed as an extension of current ICT with the potential to address the existing information exchange gap in supply chains thereby improving the chain performance.

Why another study?

While Australian retail organisations substantially employ IoT technologies in their supply chain activities, little is known about the effect of IoT on performance gains. The results of this study, conducted by Tharaka de Vass Gunawardena, a Ph.D. student at Victoria University, will be communicated to business and used to highlight the potential of IoT applications in supply chains, and help management decisions in adopting IoT for supplier and customer integration into the core internal functions. The potential finding may further deliver benefits for consumers and retailers alike by shedding light on such novel technology innovation to help improve retail productivity.

What do you have to do?

We would like to talk to your supply chain management team and interview relevant members to build a case study around IoT integration in Australian retail supply chains. The organisations will be given the option to remain de-identified and referred to using a pseudonym, and all interviewees names will also be de-identified to maintain confidentiality. An interview will take approximately an hour. The interviews will be audio recorded with your permission.

Participation in this interview is voluntary; the results will be de-identified meaning you and your organization will not be identified, and only the researchers involved in the project will have access to the information in this interview. All information will be stored in compliance with Victoria University data management guidelines.

[To add after negotiations for research concluded: we have obtained permission from your organization to conduct this research].

ALL INFORMATION WILL BE TREATED IN THE STRICTEST CONFIDENCE

What are the risks and benefits of participating?

Benefits outweigh the risk of participation. Survey fatigue and loss of time are the key risks for the participants of this research. In contrast Australian retail industry can benefit from the fact that extension from Internet-connected computers to Internet-connected devices can further strengthen supply chain information exchange mechanism to improving chain performance. Participation can help you reflect on your own organization's performance. The potential finding may guide industry practitioners with insight into the potential of IoT capabilities in integrating the supply chain processes for performance gains. The study can also contribute to policy changes favouring a decision on new investment in IoT as emerging technology application. This may further deliver benefits for consumers and retailers alike by shedding light on such novel technology innovation to help improve retail productivity.

Any questions?

For more information, please contact the Chief Investigator Dr. Himanshu Shee on (03) 9919 4077 or alternatively, at Himanshu.Shee@vu.edu.au or the Student Researcher Tharaka de Vass Gunawardena on 0410771565 or alternatively, at tharaka.devassgunawardena@live.vu.edu.au.

This project has received clearance from the Victoria University Human Research Ethics Committee. If you have any concerns about the conduct of this project, please contact the Secretary, Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001, phone (03) 9919 4781/4461 or email: researchethics@vu.edu.

CERTIFICATION BY PARTICIPANT

I, "[Click here & type participant's name]"
of "[Click here & type participant's suburb]"
certify that I am at least 18 years old* and that I am voluntarily giving my consent to participate in the study: "Internet of Things" enabled supply chain integration and performance: Australian retail industry perspectives being conducted at Victoria University by Dr Himanshu Shee.
I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by Tharaka de Vass Gunawardena and that I freely consent to participation involving the below mentioned procedures:

- Participating/Answering the interview

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.
I have been informed that the information I provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to the researcher Dr. *Himanshu Shee on (03) 9919 4077 or alternatively, at* Himanshu.Shee@vu.edu.au.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

Appendix H: Interview schedule

Semi structure interview schedule

SECTION 1: GENERAL INFORMATION

Thank you for your time.

1. How long have you been working for this organisation?
2. What is your job title?

Can you tell me about your organisation?

3. What's the nature of the retail business conducted by the organisation (what do you trade)?
4. What is the main retail form practiced by your organization (retail/e-tail/multi-model)?
5. How many employees does the organization have?
6. Where are your suppliers located? Do you consider yours a local, regional or global supply chain?
   [Explain supply chain; provide a printed diagram; emphasis the inclusion of suppliers or manufacturers, warehousing, retailer and customers and the role of logistics]

I would like to ask about your role.

7. Going back to your role, what supply chain area is your key focus (internal/supplier/customer or the entire supply chain)?
8. What are your key responsibilities and duties?
   a. [this is a probe if they don't answer #8 with this info. If they do mention it in passing, ask them to elaborate e.g. can you tell me more about your strategic role? What is your involvement? Do you have any involvement in strategic decision-making in relation to the supply chain operations and technology adoption in your organisation? What is your involvement?]

SECTION 2: IoT IN SUPPLY CHAIN OPERATIONS

So as you know I am interested in the use and impact of IoT in supply chain operations.

[Explain IoT; give participant printed list of IoT examples; give time for them to read if necessary]

9. Do you know when your organisations supply chain first adopted IoT?
10. Do you know why they decided to adopt IoT at this time? What are the key motives or drivers?

a. Probe: from that time to now, what was the progression like in terms of adopting IoT?
    i. Second probe: as in was it a fast take up, slow take up? Was it accepted by people?

11. How is IoT deployed in your business to manage the operations of your internal/in-house processes?
    i. Can you give examples of specific applications? How do they work? What are the performance outcomes of each?
        a. Probe: How does IoT help during the storage, replenishment process and product availability on the shelves?
            i. Can you give examples of specific application? How do they work? What are the performance outcomes of each?
    ii. What IoT applications and information are shared between cross functional teams/ across businesses?
    iii. Looking forward, do your intend to adopt any new IoT technologies in the near future to manage in-house operations? For what purposes? What is driving this? What are the expected outcomes?

12. How is IoT deployed currently in your business to manage the operations between your organization and suppliers?
    i. Can you give examples of specific application? How do they work? What are the performance outcomes of each?
        a. Probe: How does IoT help the transportation process?
            i. Can you give examples of specific application? How do they work? What are the performance outcomes of each?
    ii. Do you think IoT applications can improve information collection or sharing with suppliers and other upstream partners?
    iii. Looking forward, does your supply chain operation intend to adopt any new IoT technologies in the near future to manage your upstream operations? For what purposes? What is driving this? What are the expected outcomes?

13. How is IoT deployed currently in your business to manage the operations between your organization and customers?
    i. Can you give examples of specific application? How do they work? What are the performance outcomes of each?
        a. Probe: How does IoT help the delivery process?
            i. Can you give examples of specific application? How do they work? What are the performance outcomes of each?
    ii. What information is shared between your organisation and the customers? How are the relationships and the information flow managed?
    iii. What IoT applications are shared between customers and other downstream partners?
    iv. Looking forward, does your supply chain operation intend to adopt any new IoT technologies in the near future to manage your customer operations? For what purposes? What is driving this? What are the expected outcomes?

14. How does IoT deployment within your organisation affect external supply chain partners?
15. How does IoT deployment in your supply chain operation affect its overall supply chain performance of all partners (cost, quality, delivery, flexibility) ?
16. How does IoT deployment in your supply chain operation affect your organisations sustainable performance outcomes (economic, environmental and social)?

17. What do you do with the captured IoT data?
    a. Probe: Do you share them with other supply chain partners? How do you analyse? What have you found so far? What are the performance outcomes of analysis?

18. What do you think are the obstacles for IoT implementation in you supply chain operations?
    a. Probe: What do you think are the obstacles for gaining best outcomes from IoT deployment in you supply chain operations?

19. Is there anything else I might have missed that is important on IoT or to your role and organisation?

- End of interview -