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Supply chain visibility and sustainable competitive advantage: An integrated model

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Supply chain visibility and sustainable competitive advantage: An integrated model

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List of abbreviations

AC…………………..Absorptive Capacity
ANSI………………..American national Standards institute
BC……………………Bias-Corrected
CA ……………………Competitive Advantage
CCD…………………..Charge Coupled Device
CCTV………………...Closed Circuit Television
CIs……………………Confidence Intervals
CIPS …………………Chartered Institute of Purchasing and supply
CPFR……… ………..Collaborative Planning, Forecasting and Replenishment
CRP …………………Continuous Replenishment Program
CSCMP………………Council of supply Chain Management Professionals
CTM …………………Collaborative Transportation Management
DC …………………...Distribution Centre
DOD…………………Department of Defence
e.g.…………..……….exempli gratia *(Latin)*; for example
etc………….. ………..et cetera *(Latin)*; and the rest, and so forth
ECR…………………..Efficient Consumer Response
EDI…………. ……….Electronic Data Interchange
EEC…………………...European Economic Community
EFA………………......Exploratory Factor Analysis
EM……………………Expectation Maximisation
EPC………………….. Electronic Product Code
EPOS…………………Electronic Point of Sale
ERBV………………..Extended Resource Based View
ERP.…………………Enterprise Resource Planning
FA……………………Factor Analysis
FMA………………….First Mover Advantage
FMCG………………..Fast Moving Customer Goods
GDSN………………. Global Data Synchronization Network
GPS…………………..Global Positioning System
HF……......................High Frequency
i.e. …………………...id est *(Latin)*; that is
IP……………………..Internal Protocol
ICT …………………..Information Communication Technology
IS ……………………Information System
IT ……………………Information Technology
KMO………………….Kaiser-Meyer-Olkin
LF……………………Low Frequency
MW…………………..Microwave
NGOs………………...Non-Governmental organisations
OCR………………….Optical Character recognition
ONS………………….Object Name Service
PCA………………….Principal Component Analysis
RBV………………….Resource Based View

RFID ………………...Radio Frequency Identification Device
ROI…………………..Return on Investment
RTAs…………………Returnable Transport Assets
RTAM ……………….Returnable Transport Asset Management
RTLS…………………Real Time Location System
RV …………………...Relational View
SC …………………...Supply Chain
SCA ………………....Sustainable Competitive Advantage
SCM ………………....Supply Chain Management
SCP………………... Supply Chain Partner
SMEs…………………Small and Medium size enterprises
TCE ………………....Transaction Cost Economies
TOP ………………....Traditional Ordering Process
UHF………………….Ultra High Frequency
UPC………………….Universal Product Codes
VIF…………………..Variable Inflation Factor
VMI …………………Vendor Managed Inventory
VRIN………………...Valuable, Rare, Inimitable, Non-substitutable
WMS…………………Warehouse Management System
XML ………………...Extensible Markup Language
3G……………………Third Generation
3PL ………………….Third Party Logistics

Executive summary

Lack of visibility of the assets in a product supply chain compromises attempts to optimise supply chain management. Increasing the visibility of these assets presents a relatively unexplored frontier in operations and supply where organisations can create competitive advantage through the opportunities asset visibility offer. This research aims at investigating the key capabilities of asset visibility specifically those associated with returnable transport assets that travel across supply chains carrying material and products e.g. cages, boxes, trays, trolleys and pallet bins. In addition, how these capabilities may influence supply chain visibility and firm performance in a way that might lead to sustainable competitive advantage is examined.

To achieve these objectives, the research develops a two-stage model that is theoretically grounded in the extended resource-based view. Philosophically, the research adopts a critical realist approach using abductive logic. Methodologically, a sequential exploratory strategy for data collection is implemented. A qualitative, in-depth site-based case study supported by field expert interviews was conducted as a pilot study. The pilot study findings refined the initial conceptual model derived from literature and informed the next stage of the research. The quantitative phase focused on refining the factors constituting asset visibility capabilities and then testing the relationship between these capabilities and supply chain visibility, performance and sustainable competitive advantage.

Key findings are that asset visibility capabilities are shaped through three key capabilities: (1) an asset management capability formed by both core technological aspects related to tracking and tracing technology, and non-technological ones focusing on logistic-related capability; (2) a complementary technological capability comprising of IT infrastructure for supply chain integration; and (3) a complementary non-technological capability represented through three sub-capabilities: (a) supply chain process integration; (b) focal firm-3PL relational orientation; and (c) internal firm integration.

The research findings prove a positive relationship between asset visibility capabilities and supply chain visibility. In addition, a positive relationship between these capabilities and sustainable competitive advantage through the mediated effect of supply chain visibility and firm performance, is confirmed.

Chapter 1: Introduction

1.1 Introduction

Following the logic of figure 1-1, this chapter provides an overview of the research context (1.2), the research gap identified in the literature (1.3), the research questions (1.4), the scope of the study (1.5), the objectives of the research (1.6), the research plan (1.7) and the significance of the study (1.8). In addition, the initial conceptual model (1.9), philosophical and methodological stances are introduced (1.10) and finally, the research structure is presented (1.11) followed by a summary of the chapter (1.12).

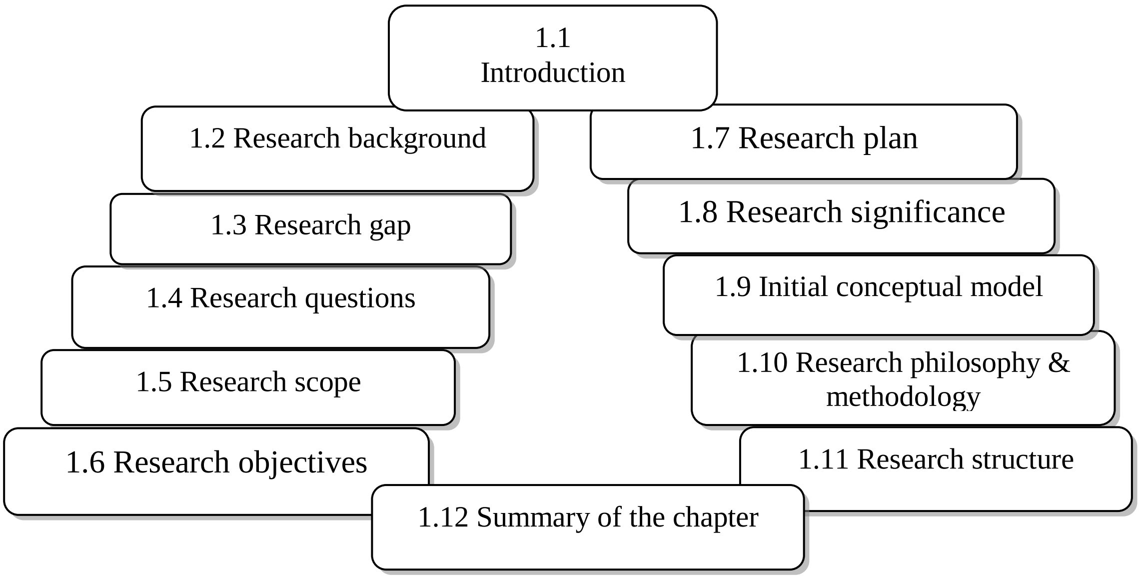

Figure 1-1: **Structure of chapter one**

1.2 Research background

A supply chain is the key unit of competitiveness in today's business environment. Supply chain management has emerged as a new managerial approach that consolidates already well established business functions and operations on an aggregated level (Harland, 2006; New, 1997). This approach aims at improving performance, profitability and competitiveness of supply chain trading partners. Yet, contemporary supply chains are exposed to a variety of risks including supply disruption, supply delays and demand fluctuations. As such, real-time systems and rapid response supply chains have become the key strategies for business survival and continuity (Chopra & Meindl, 2007; Christopher, 2000; Gunasekaran, Lai, & Cheng, 2008).

Visibility of information is an antecedent for real-time systems, responsive and reliable supply chains (Arntzen, Brown, Harrison, & Trafton, 1995; Li & O'Brien, 1999). Previous work has claimed that many business problems are mainly associated with poor supply chain visibility (SCV), (Christopher, 2004; McFarlane & Sheffi, 2003). SCV is limited by the complexity of supply chain activities, especially in product supply chains where the physical flows of material and products are performed through an intricate web of relationships and distribution networks. In addition, SCV is constrained by a considerable amount of manual labour involved in checking and managing received and shipped products (Christopher, 2004; McFarlane & Sheffi, 2003).

Enhancing SCV is associated with making assets visible at an operational level, an approach that is directly linked to how to manage the physical flow of material and products across complex supply chains. In this study, the basic unit of managing and controlling this flow is focused on the examination of returnable transport assets (RTAs) that travel across supply chains carrying material and products (e.g. boxes, crates, pallets, drums). Visibility of RTAs can be a key enabler to the smooth flow of goods across supply chains (Ilic, Ng, Bowman, & Staake, 2009b; Johansson & Hellström, 2007). However, asset visibility is still a major challenge for enhancing SCV because current returnable transport asset management systems remain manual and error-prone processes, resulting in high labour costs, asset shipping errors, manufacturing outages, delivery errors and dissatisfied customers (Kelepouris, Theodorou, McFarlane, Thorne, & Harrison, 2006b; Martinez-Sala, Egea-López, Garcia-Sanchez, & Garcia-Haro, 2009; Roussos, 2006). This research focuses on asset visibility within returnable transport asset management practices as a key component of enhanced SCV and in turn performance. The research takes as its starting point the view that innovative data capture technology such as radio frequency identification devices (RFID), are important in improving visibility in supply environments of any significant complexity.

1.3 The gap in the research literature

Asset visibility at an operational level is the crux of SCV. However, asset visibility is less well articulated within supply chain literature due to a considerable overlapping between SCV and asset visibility concepts (Francis, 2008; Johansson & Hellström, 2007; Zhang, He, & Tan, 2008). Supply chain visibility is constrained at an operational level due to the obsolescence of asset management systems. In current supply chains, visibility is limited to the financial flow of orders rather than the actual flow of products (Fawcett & Magnan, 2002). Hence, poor asset visibility undermines SCV and in turn performance. The unprecedented level of complexity shaping current supply chain, logistics activities and relationships (Choi & Krause, 2006; Meepetchdee & Shah, 2007; Pathak, Day, Nair, Sawaya, & Kristal, 2007), accompanied by a proliferation of innovative data capture technology that is expected to be the next big trend in supply chain management (Indranil & Raktim, 2005; Ley, 2007), has enhanced the significance of asset visibility as a way of attaining SCV. As such, it is expected that improved asset management practices are likely to improve performance and in turn sustainable competitive advantage (SCA).

The significant role that asset visibility plays in the management of current supply chains requires a sophisticated appreciation of the capabilities required for asset visibility. Understanding these capabilities is especially necessary given the growing awareness that the delivery process and logistics activities can become a source of competitive differentiation as much as the product itself (Bhatnagar & Teo, 2009; McDuffie, West, Welsh, & Baker, 2001; Mentzer, Flint, & Hult, 2001b; Muller, 1991).

It is contended that there is a gap between academics and practitioners in the area of asset visibility (Ngai, 2009). To date, academic research within an operations and supply chain context is in its infancy in the domain of asset visibility and its impact on SCV, performance and SCA. Therefore, this study focuses on exploring the capabilities required to make the assets in a supply chain visible and how these capabilities can be a source of SCA.

1.4 The research questions

The research seeks to answer the following three main questions:

1) *What are the capabilities that constitute managing assets for visibility?*
2) *How can these capabilities be used to enhance supply chain visibility?*
3) *How do the capabilities required for visibility impact firm performance and in turn, sustainable competitive advantage?*

1.5 Research scope

This research focuses on the asset visibility capabilities associated with returnable transport asset management practices across downstream supply chain activities; specifically transport logistics activities, see figure 1-2. The intention is to understand the link between these capabilities and SCV, firm performance and SCA.

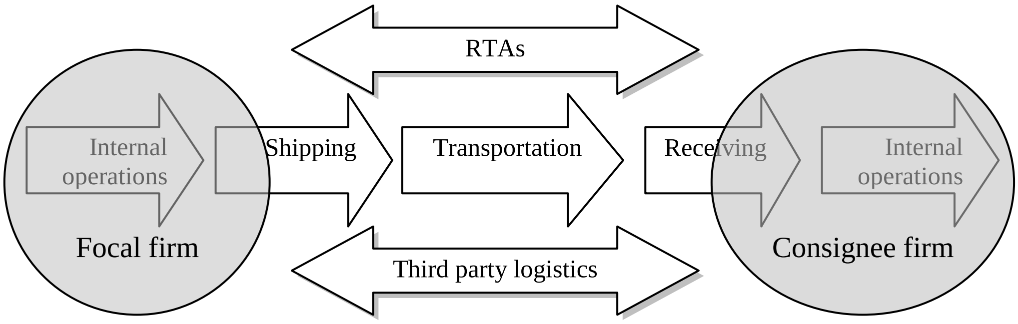

Figure 1-2: **Research scope**

1.6 Research objectives

To answer the research questions the following two objectives are central:

- To explore the key capabilities of asset visibility;
- To investigate how these capabilities may impact SCV and firm performance that may lead to SCA.

1.7 Research plan

This section depicts the research plan to achieve its objectives, see figure 1-3.

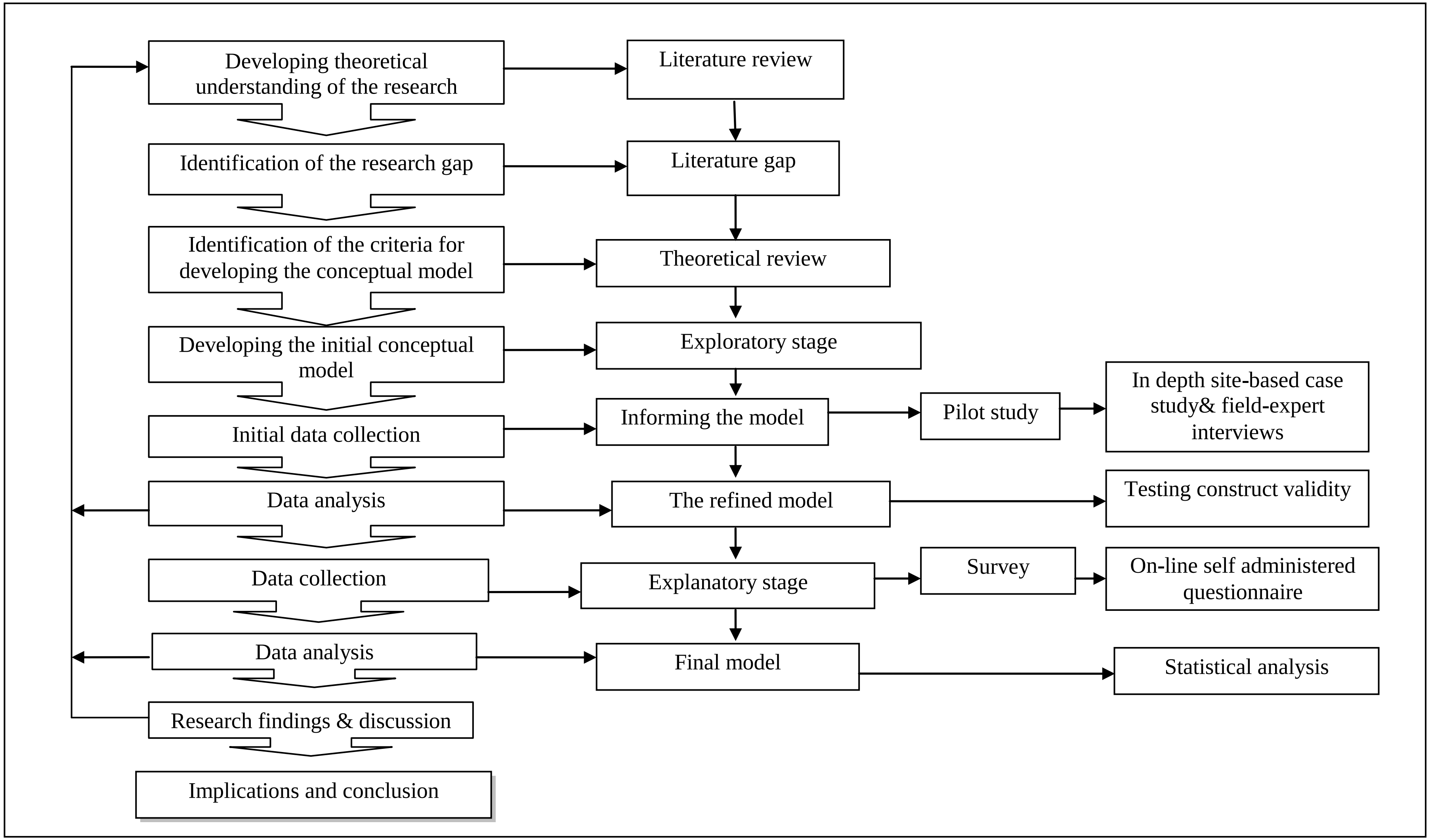

Figure 1-3: Research plan

1.8 Research significance

This section presents respectively the academic and managerial significance of the study.

Academic significance

Major retailers such as Wal-Mart in USA, Tesco in the UK, 7-Eleven in Japan, and Metro in Germany are prominent users of asset visibility driven by innovative data capture technology, specifically RFID (Dutta, Lee, & Seungjin, 2007; Wamba, Lefebvre, Bendavid, & Lefebvre, 2008). However, the mechanism through which asset visibility can affect SCV and performance resulting in SCA is still under-researched (Lee & Ozer, 2007). It is argued that innovative IT applications are significant for better supply chain performance, albeit there is a scarcity of theory supporting these initiatives (Straub, Rai, & Klein, 2004). This study builds its academic significance as follows:

- This study is the first academic initiative towards developing a comprehensive perspective of asset visibility capabilities within a supply chain context which is informed by both theory and practice.
- This study contributes in verifying the assumptions of the extended resource based view (ERBV). Although ERBV has been around for more than twenty years, its assumptions still need more academic work to be verified within the operations and supply chain context.
- This study participates in reshaping the SCV construct by investigating asset visibility at an operational level as a sub-construct of SCV. A review of the literature revealed an overlap between the two constructs (Francis, 2008).
- This study clarifies the significance of innovative asset management practices within transport logistics in reshaping supply chain relationships.
- This study provides a managerial model for asset visibility capabilities as a source of SCA. This model is driven by an integrated supply chain construct that might be useful in informing further supply chain research, avoiding the limitations of a uni-dimensional view.

Practical significance

A survey in the UK proposed that 40% of gross domestic product was spent in logistics and distribution activities whilst in US, these activities contribute almost 60% of the total product cost (Gunasekaran et al., 2004). Thomas and Griffin (1996) argue that transport logistics cost occupies more than half of total logistics costs highlighting the need for more academic research in this area. Returnable transport assets are the basic physical units used in supply chain transport logistics activities. It is contended that attaining visibility at the returnable transport asset level can be a key enabler of smooth flow of goods across supply chains (Ilic et al., 2009b). This might enhance SCV and firm performance resulting in SCA. Hence, the research is of practical significance for the following reasons:

- To provide a model for SCV driven by asset visibility capabilities that may help firms to enhance performance and competitiveness.
- To inform business decision makers about the pre-requisite capabilities of asset visibility at an operational level that are directly influenced by asset management systems. Such understanding would enable the adoption of more innovative systems and ensure improved performance against current systems.
- To participate in filling the research gap between academics and practitioners in the area of asset visibility (Ngai, 2009).
- To draw on the changes in the supply and logistics environment that require more empirical research.
- To contribute in filling the credibility gap of innovative data capture technology (specifically RFID) where more academic research in the area of operations management is needed to prove its value (Lee & Ozer, 2007).
- This study supports sustainability as an environmental implication through its focus on visibility of returnable transport assets; better asset management practices enhance sustainability.

1.9 Initial conceptual model

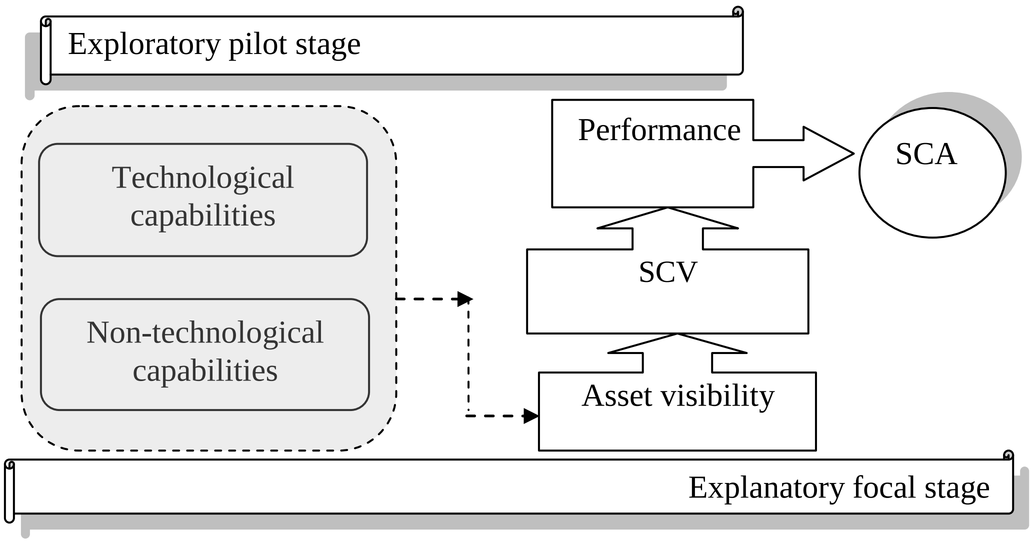

Figure 1-4: **Initial conceptual model**

The resource-based view has a limited focus on the firm's internal resources through which SCA can be attained (Barney, 1991; Fahy, 2003). On the other hand, the extended resource-based view (ERBV) illustrates how SCA may be gained through relational resources that span firms' boundaries (Lavie, 2006; Lewis, Brandon-Jones, Slack, & Howard, 2010). Asset visibility is associated with RTAs as dynamic resources at an operational level span firms' boundaries. As such, this research mainly adopts the ERBV as an appropriate theoretical construct.

As illustrated in figure 1-4, the research develops a two-stage model; the exploratory pilot stage informs the explanatory focal stage. SCV enablers are classified in terms of technological and non-technological aspects (Barratt & Oke, 2007). The research employs this initial classification when exploring asset visibility capabilities. The impact of these capabilities on SCV and in turn firm performance is investigated within the exploratory stage. This effect, along with the effect on SCA, will be examined later within the focal stage.

1.10 Research philosophy and methodology

Philosophically, this research adopts a critical realist approach based on abductive logic which has become an important perspective in modern philosophy and social science (Archer, Bhaskar, Collier, & Lawson, 1998). Critical realism is appropriate for this research due to the novelty of the research phenomenon which entails uncovering unknown information. This may lead to development of new knowledge and may be generalisable under certain conditions. This new knowledge is informed by empirical observation that considers participants' values and then tests hypotheses through empirical application.

Methodologically, this research adopts a sequential exploratory strategy for data collection. As such, the research starts with a pilot study aiming at qualitatively exploring asset visibility capabilities and investigating their impact on SCV and firm performance. To this end, an in-depth site-based case study supported by field-expert semi-structured interviews is conducted. For the purpose of cross-validation of the research findings, triangulation is considered at this stage. With respect to the focal stage, a quantitative examination of these capabilities and their influence on SCV as well as on SCA is performed using an on-line survey.

1.11 Research structure

This section discusses the structure followed in this study in relation to the key purpose and the main points discussed within each chapter. (Figure 1-5).

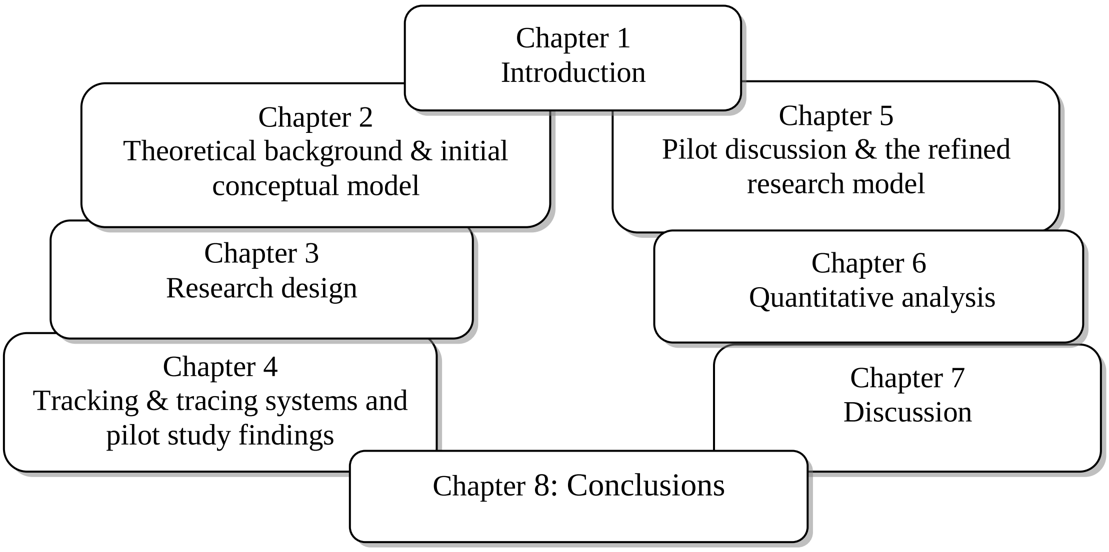

Figure 1-5: **Research structure**

Chapter two relates to the research objectives by developing a theoretical understanding of the research phenomenon. As such, the chapter starts with the theoretical background of supply chain management and its relation to performance and competitive advantage. The chapter introduces ERBV and its assumptions that inform the research model. As the focal interest of the research, this chapter discusses SCV with a special focus on asset visibility as a sub-construct and its significance in managing current supply chains.

This chapter concludes with the initial conceptual model, which aims at exploring the key capabilities of asset visibility and their impact on SCV and firm performance.

In chapter three, the research transformation process from purely theoretical origins into a philosophically and methodologically applicable piece of research is presented. This chapter presents the research philosophy and methodological considerations, to illustrate how key research decisions were made. The former focuses on the key philosophical assumptions, the notion of pluralist of paradigms, the research logic, the main approaches to social science and the employed research approach. The latter part is concerned with the practical considerations of social research that are associated with decisions on research strategy and time horizon. Based on the chosen strategy, the mixed methods approach and data collection strategy are explained. This chapter closes by discussing data quality issues and the operationalisation process of the variables employed.

Chapter four starts with illustrating the concepts and the different perspectives of tracking, traceability and visibility. The chapter then draws on some examples of tracking applications. The problems related to poor tracking practices the businesses encounter are then explained. This is followed by discussing business problems associated with poor RTAs tracking practices as the key focus of this study. The merits of tracking, tracing and visibility are highlighted with a particular focus on those related to RTAs. The chapter then demonstrates in detail the key types of tracking systems incorporating low-tech and high-tech tracking systems. The chapter then presents illustrative examples of integration and coupling of tracking applications. The chapter ends this section with a summary of tracking applications. The second section of the chapter introduces the exploratory pilot stage of the research through which the key capabilities of asset visibility are investigated along with their effect on SCV and firm performance. In this chapter, data quality issues within the pilot study are tackled. In addition, the background and a detailed description of the main case study are provided. Finally the key findings of the pilot study are presented.

Chapter five focuses on a discussion of the pilot study findings in order to refine the initial conceptual model. The pilot discussion ends by positing a number of hypotheses examining the effect of asset visibility capabilities on SCV for further empirical investigation. The chapter then theoretically develops the research hypotheses concerned with the mediated effect of asset visibility capabilities on sustainable competitive advantage. This hypothetical development finishes with a number of hypotheses for empirical investigation.

Chapter six presents a quantitative investigation of the survey data examining asset visibility and its impact on SCV, performance and SCA. Prior to this investigation, the chapter examines the appropriateness of the data before conducting the analysis. For the purpose of creating the construct measurement of the study, exploratory factor analysis is conducted. To ensure the quality of the employed scale and measures, their validity and reliability are examined. The refined research model is then tested using suitable techniques for the hypothesised relationships (mainly standard multiple regression and bootstrap multiple mediation). The chapter reports the key finding of these statistical tests.

Chapter seven discusses the findings of the survey study. The survey aimed at answering the research questions through testing the hypothesised relationship between the asset visibility capabilities of a focal firm and SCV, as well as the mediation relationship between these capabilities and SCA. The chapter draws on the findings of each of the hypothesised relationships represented through ten key hypotheses. The discussion of this chapter is informed by the results of the quantitative data analysis introduced in chapter 6.

Finally, chapter eight presents conclusions, revisiting the research model, objectives and questions. It also draws briefly on the key findings and their managerial, theoretical, methodological and practical implications. Moreover, limitations of the research that might affect generalisability of findings are introduced. In conclusion, recommendations for future research are made.

1.12 Summary of the chapter

This chapter intended to provide an overview of the research context, the gap found in the literature, key research questions, scope, main objectives, the research plan to achieve these objectives and the research importance. In addition, the initial conceptual model and the philosophical and methodological stances that were adopted to investigate this model were illustrated. Ultimately, the chapter illustrated the structure of the thesis.

Chapter 2: Theoretical background and initial conceptual model

2.1. Introduction

This chapter seeks a theoretical understanding of the research phenomenon associated with supply chain visibility mainly through enhancing asset visibility and the influence of this visibility on firm performance and competitive advantage. As depicted in figure 2.1, this chapter starts with providing a theoretical background pertaining to supply chain management (SCM) and its impact on firm performance and competitive advantage. In addition, the theoretical perspective adopted in this study is introduced. In section 2.3, supply chain visibility and its significance are emphasised. Section 2.4 provides a special focus on asset visibility and its significance in managing supply chains. Section 2.5 develops the research's initial conceptual model that will be empirically investigated. Section 2.6 completes the chapter with a summary of the chapter content.

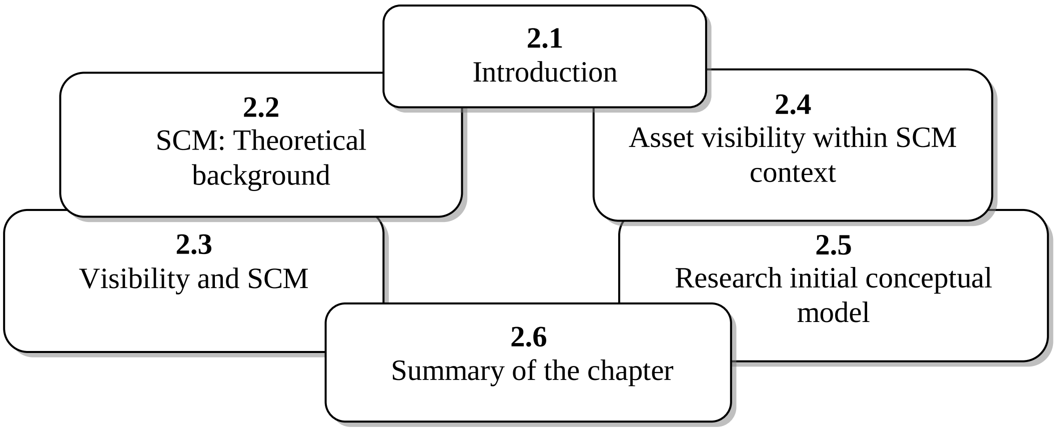

Figure 2-1: **Structure of the chapter**

2.2. SCM: theoretical background

This section provides a brief overview of the supply chain concept and supply chain management as key concepts that inform this study. The significance of logistics, inter-firm relationships and information technology in managing today's supply chain are presented. The influence of SCM on firm performance and competitive advantage are depicted. As the theoretical perspective adopted in this research, the resource-based view and its assumptions for sustainable competitive advantage (SCA) are explained and the emergence of the resource-based view in IT research is discussed. The section also introduces the extended resource-based view as an extension of the original resource-based view. Then follows the theoretical foundation of supply chain competitive advantage. The section ends with an evaluation of competitive advantage within a supply chain context.

2.2.1 The supply chain concept

The operations management and supply chain literatures have shown some agreements on the definition of a supply chain. La Londe and Masters (1994) define a supply chain as a group of firms through which materials and products pass forward to end users. Christopher (1992) defines a supply chain as a network of organisations working in different activities and processes through upstream and downstream linkages to get value from producing products and delivering services to end customers. From analytical perspective, "*supply chain is simply a network of materials, information and services processing links with the characteristics of supply, transformation and demand*" (Chen & Paulraj, 2004b, p.132). In their definition, Mentzer, DeWitt, Keebler, Soonhoong, Nix, Smith, and Zacharia (2001a) indicate three levels of supply chain complexity: *direct supply chain* including a focal firm, a supplier and a customer; *extended supply chain* including suppliers of the intermediate supplier and customers of intermediate customer; and *ultimate supply chain* including all firms engaged in both supply and logistics activities. In addition to these three levels, Harland (1996) added another dimension pertaining to the *internal supply chain* that entails integration between internal business activities and functions, for a smooth flow of materials and products to end users.

Drawing on these definitions the supply chain concept has two key dimensions: a *functional dimension* that mainly includes supply, manufacturing and logistics functions, and a *relational dimension* that expresses levels of intra/inter-firm relationships through which supply chains are managed. Hence, the internal supply chain is managed through intra-firm relationships whilst inter-firm relationships are adopted to manage a number of interacting supply chain trading partners (Straub et al., 2004).

Different complexity levels of network structure influence different patterns of inter-firm relationships. A dyadic network is managed through a dyadic relationship, that is the simplest form of a network structure representing two firms. A complex network contains a multitude of inter-firm relationships including all interacting supply chain firms. A complicated network lies between the dyadic and complex network;

"*complicated system can be intricate, yet the relationship between the components is fixed and well defined, while, complex system is characterized as a nonlinear dynamics interaction of the individual parts*" (Pathak et al., 2007, p.559). Thus, a complex network is the best representation of today's supply chain structure and relationships.

2.2.2 SCM concept

Although SCM is a popular term used in both academia and practice, there is still no agreement on its definition or even on the description of its construct (Burgess, Singh, & Koroglu, 2006; Chen & Paulraj, 2004a; Harland, 2006; Mentzer et al., 2001a; New, 1997; Saunders, 1998). Supply chain management is still an immature area of research, that only emerged in the early 1990s (Cooper, Lambert, & Pagh, 1997). As an area of research SCM is influenced by a number of functions such as operations management, marketing, purchasing and supply, logistics and physical distribution, management information systems, organisational theory and strategic management.

The Council of Supply Chain Management Professionals (CSCMP) (2007) has defined SCM as "*an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model".* Vaaland and Heide (2007) assert that although there is no agreed definition for SCM, there is an agreement that SCM covers all business processes between vertically linked organisations. The Global Supply Chain Forum has defined supply chain management as " *the integration of key business processes from end user through original suppliers products, services, and information that add value for customers and other stakeholders*" (Lambert & Cooper, 2000, p.66). In his definition, Christopher (2005, p.5) focuses on supply chain relationships: *"the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole".* Fisher (1997) and Cooper et al. (1997) propose SCM as the planning and control of the flows of materials, information and logistics activities whether internally (within the firm) or externally (across firms). Mentzer et al. (2001a, p.18) tried to find a unified definition for SCM. They conclude that SCM is defined as "*the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain* *as a whole*". In a structured literature review of SCM, Burgess, Singh, and Koroglu (2006) adopted this definition.

Vaaland and Heide (2007) indicate three perspectives for defining SCM: *actor-oriented definitions* focusing on managing the flow of materials from first supplier to the end customer; this dimension is oriented more towards logistics activities (e.g. Chen & Paulraj, 2004a), *relation-oriented definitions* concerned with managing the relationship between supply chain partners (e.g. Christopher, 2005; Harland, Lamming, & Cousins, 1999), and *process oriented definitions* concerned with managing supply chain activities and processes mainly through virtual linking (e.g. Lambert, Cooper, & Pagh, 1998). Vaaland and Heide (2007) claim that a comprehensive SCM concept should consider the integration between these three perspectives. In the following sections, the research draws on these three dimensions emphasising the role of logistics, inter-firm relationships and IT in managing today's supply chains.

2.2.3 Significance of logistics in SCM

Some literature tends to deal with supply chain management and logistics as synonymous and interchangeable terms (Stephens & Wright, 2002). Bowersox and Closs (1996) and Lambert et al. (1998) treat SCM and integrated logistics systems as synonymous. In their study, Larson and Halldorsson (2004) assert that there is a lack of agreement on the relationship between SCM and logistics. The same authors introduced four conceptual perspectives for logistics versus SCM. The first perspective, *traditionalist,* considers SCM as a small part of logistics. The second, *relabeling,* renames logistics as SCM i.e. that both are synonymous. The third, *unionist,* sees logistics as a part of SCM i.e. SCM is more than logistics. The fourth, the *inter-sectionist* perspective, treats SCM as a broad strategy not as a subset of logistics i.e. SCM is a strategic not a tactical function that deals with whole business processes within the firm and across the channels. Larson and Halldorsson (2004) concluded that, in practice all the four perspectives of SCM versus logistics are valid. Mentzer et al. (2001a) and Croom, Romano and Giannakis (2000) argue that SCM should include all the traditional business functions i.e. production, marketing, sales, forecasting, research and development, logistics, finance, information systems and customer service.

In his framework of supply chain literature, Tan (2001) classifies supply chain management literature into two key perspectives: *purchasing and supply,* and *transportation and logistics*. Although Lamming (1996) initially focused on purchasing and supply as a perspective for SCM, he concluded that SCM is a theory that originated in logistics. Logistics has continued to have significant influence on the SCM concept (Jones & Riley, 1985). The Council of Logistics Management (1998) considers logistics as one function of supply chain functions.

Although, many studies have tried to draw on the differences between the two concepts (e.g. Cooper et al., 1997; Tyndall, Christopher, Wolfgang, & John, 1998) this research does not focuses on the division between the two concepts i.e. logistics and SCM. The assumption made in this study is that this division is no longer useful given the increasing integration of modern supply with integrated physical and non-physical SCM functions and activities. From an analytical perspective, this research argues that *SCM is an integrated management system that combines upstream and downstream business functions, and activities linked in a value chain*. The research also contends that logistics activities pertain mainly to the operational level whilst the supply chain encapsulates various organisational levels including operational, tactical and strategic.

Within the SCM context, logistics represents integrated physical activities that span a firms' boundaries, adding value throughout the entire value chain from suppliers (inbound logistics) to customers (outbound logistics) (New & Payne, 1995). Therefore, SCM is taken to cover logistics along with other business functions and acting cooperatively to inform operational, tactical and strategic business decisions within and across firms.

2.2.4 Significance of inter-firm relationships in SCM

Supply chain partnerships or collaborative supply chains are based on cooperation among independent but related firms that share resources and capabilities to create a competitive advantage (Bowersox, Closs, & Stank, 2000; Dyer & Singh, 1998; Narus & Anderson, 1996; Simatupang & Sridharan, 2005). Liu, Zhang and Hu (2005) stated that the key enablers of supply chain success are data management capabilities, effective management of strategic alliances, and innovative inter-organisational systems. Supply chain collaboration based on long-term relationships is often recommended for managing today's supply chains rather than adversarial relationships and opportunistic behaviour (Hoyt & Huq, 2000; Madlberger, 2008; Zheng, Roehrich, & Lewis, 2008). Inter-firm relationships determine the scope (in terms of supply chain activities) and the scale (in the form of organisational levels including operational, tactical and strategic) of integration and collaboration among supply chain trading partners. It is often proposed that strong ties exist among firms linked in a value chain facilitates the flow of information, products, materials, or any other resources across a supply chain (Handfield & Nichols, 1999; Patnayakuni, Rai, & Seth, 2006).

In the past logistics was often seen as a clerical function implying antagonist relationships between supply chain actors including suppliers, customers and third party logistics. However, logistics has increasingly come to be seen as a source of competitive differentiation and the main influential factor of the incremental trend towards inter-organisational systems (Lewis & Talalayevsky, 2004). Bowersox (1990), Handfield and Bechtel (2002) argued that the trend towards supply chain collaboration and strategic alliances was due to the impact of fierce competition, globalisation, leaner organisations and the explosion of information technology. Thus, firms and their trading partners are eager to explore new ways of working together for mutual gains resulting in better performance and gaining competitive position (Li, Ragu-Nathan, Ragu-Nathan, & Subba, 2006a; Tan, Kannan, Handfeld, & Ghosh, 1999).

2.2.5 The significance of IT in SCM

Information technology (IT) is defined as "*any form of computer-based information systems*" (Orlikowski & Gash, April 1992). It refers to "all forms of technology utilised to create, capture, manipulate, communicate, exchange, present and use information in its various forms" (Ryssel & Ritter, 2004, p.198). The emergence of SCM as a new managerial trend coincided with new and complementary developments in IT systems and applications. Table (2-1) shows three generations of IT before and after the evolution of SCM.

Table 2-1: IT generation in business environment

Generation	***Focus***	***Features***
1st Generation 1970s-1980s	Systems as standalone applications for managing internal firm's processes.	Increasing functionality and sophistication of IT applications.
2nd Generation 1990s	Systems as integrated sets of components for managing internal firm's processes.	- Increasing the complexity and interdependency among IT systems; - Increasing the demand for IT applications and software for internal integration and collaboration.

3rd Generation Late 1990s to 2000s	- IT systems and applications for managing internal and external supply chain activities and functions. - IT architecture for dynamic supply chains.	- The emergence of internet and web-based technology, e-commerce, as well as business-to-business applications - The increase of interdependency between firms - The adoption of knowledge management and systems thinking.

Source: Adapted from (Evernden & Evernden, 2003).

Today's business environment is dynamic in nature and electronically connected, causing firms to be under pressure to enhance their competitiveness. Time has become one of the key competitive determinants (Handfield & Pannesi, 1995; Stalk, 1988; Yusuf, Gunasekaranb, Adeleyec, & Sivayoganathan, 2004). Therefore, firms try to develop the ability to be more responsive and flexible in managing their dynamic supply chains (Gunasekaran & Ngai, 2004). Enhancing information capability has become one of a firms most valuable resources, with the adoption of innovative IT applications as a primary enabler for managing the supply chain effectively. As firms become electronically linked to their supply chain partners through inter-organisational systems (Byrd & Davidson, 2003; Gunasekaran & Ngai, 2004), SCM has become one of the major organisational practices. As such, IT plays a crucial role in managing current supply chains.

SCM is considered a significant field for IT innovation and investment (Bowersox & Daugherty, 1995), so that scholars from the strategic management domain have begun to focus on the IT role as a competitive weapon for supply chains (e.g. Parsons, 1983; Porter & Millar, 1985; Powell & Dent-Micallef, 1997). How IT can be a source of sustainable competitive advantage is of significant interest to academics and practitioners)e.g. Bhatt & Grover, 2005; Christopher, 2000; Dehning & Stratopoulos, 2003; Johnston & Vitale, 1988; Wu, Yeniyurt, Kim, & Cavusgil, 2006a(.

2.2.6 SCM and firm performance

Firm performance is influenced by both internal firm practices and external practices with supply chain trading partners (New & Payne, 1995). As such, firm performance is shaped through the integration of internal and external firm's practices (Flynn, Huo, & Zhao, 2010). It is agreed that SCM initiatives that support integration and collaboration between trading partners, are able to enhance firm performance (e.g. Flynn et al., 2010; Tan et al., 1999; Tracey, Lim, & Vonderembse, 2005).

With respect to the supply chain context, the focal interest is in improving supply chain performance as an aggregated unit, thereby enhancing performance across the different levels (operational, tactical and strategic) and across firms linked in a value chain. Many studies have highlighted the impact of distortions of logistics information across a supply chain on operational performance (e.g. Edghill, Olsmats, & Towill, 1988; Harland, 1997). It is argued that SCM initiatives alone are not sufficient to enhance delivery and cost performance, unless new technologies and markets are pursued (Tan et al., 1999). Although innovative IT applications are significant levers for improving supply chain performance; there is a scarcity of theory guided initiatives (Straub et al., 2004). Furthermore, Straub et al. (2004) argued that most studies that have investigated the influence of these innovative applications on supply chain activities, were limited to the constructs of capabilities on the firm level (e.g. Aral & Weill, 2007; Dale Stoel & Muhanna, 2009). Recently, studies have paid more attention to the supply chain construct when investigating the impact of innovative IT capabilities on performance, in particular those related to inter-organisational systems (e.g. Frohlich, 2002; Straub et al., 2004).

Despite the theoretical appeal of inter-firm or network performance measurements to evaluate supply chain performance, current business systems are generally not mature enough to implement these measures beyond more than two nodes or partners (New & Payne, 1995; Straub et al., 2004). The literature has shown increasing interest in studying the impact of supply chain practices on dyad network performance (e.g. Hsu, Kannan, Tan, & Leong, 2008; Humphreys, Li, & Chan, 2004). Taken together, most of studies still tend to measure the impact of supply chain initiatives on firm performance level as opposed to network level performance which might include dyad, triad, quadrad (four nodes), or quintrad (five nodes), etc.

In reviewing the operations and supply chain literature, there appears to be an overlap between firm performance and competitive advantage and the measurement process. Performance measurement is defined as "*the process of quantifying the effectiveness and efficiency of action*" (Neely, Gregory, & Platts, 1995, p.1229). Effectiveness indicates to what extent customers' needs are met, whilst efficiency refers to the extent to which resources are economically utilised (Shepherd & Gunter, 2006). Due to the lack of agreement on a valid cross-industry indicator of firm performance (Tan et al., 1999), a variety of measures are employed and the same measures are sometimes used to indicate firm performance as well as competitive advantage, especially financial measures such as return on investment and return on assets. It is contended that local performance measures that consider alignment with strategic goals, firm culture and reward systems should be encouraged in preference of the use of potentially inadequate benchmarking measures (Shepherd & Gunter, 2006).

2.2.7 SCM and competitive advantage

Supply chain management plays a substantial role in gaining a competitive position (Porter & Millar, 1985). It is asserted that effective supply chain practices are able to attain sustainable competitive advantages (Cooper et al., 1997; Li et al., 2006a; Tracey et al., 2005). Only above-average performance compared to a firm's rivals or the industry average is the key measure for competitive advantage (Adegbesan, 2009).

The supply chain concept has altered the traditional pattern of competition of firm-based competition to supply chain-based competition (Lambert & Cooper, 2000; Yusuf et al., 2004). Dyer (1994) asserts that competition is now between production and distribution networks or value chains and not between individual firms. This new pattern is built on inter-firm collaboration and cooperative networks (Christopher & Juttner, 2000). Competitive advantage in the supply chain context refers to the extent to which a supply chain is able to create an advantage over its rivals. This concept has changed the basis of competition from a price or financial orientation only, towards a service orientation, which in turn reflects the association between the SCM concept and cycle time compression (Li & O'Brien, 1999; Towill, 1996). This new competitive paradigm justifies the transformation in the supply chain literature from focusing on building models (financial-oriented models) for optimising supply chain operations based on reducing operational cost (e.g. Cohen & Lee, 1988; Das & Tyagi, 1994), towards optimisation models (service-oriented models) based on improving supply chain responsiveness and reliability (e.g. Arntzen et al., 1995; Li & O'Brien, 1999).

Responsiveness is mainly associated with the agility of a supply chain. Hence, the literature has proposed that in addition to price; quality, delivery and flexibility have been identified as important competitive capabilities (Tracey, Vonderembse, & Lim, 1999). Besides, time-based competition has emerged as a key source for firm's competitive advantage (Handfield & Pannesi, 1995; Stalk, 1988; Yusuf et al., 2004). Time is primarily influenced by logistics activities (Bhatnagar & Teo, 2009).

The historical view of logistics as a narrow functional activity focused on cost meant that it was under utilised as an element of a firm's competitive strategy (Stock, 1998). Currently, because of the substantial transformations in the business environment e.g. the emergence of new management techniques such as lean and just in time systems, intensive competition, and the evolution of innovative information communication technology (ICT) and inter-organisational systems (IOS); logistics has embarked upon employing a significant role within firms and across supply chains. Logistics has become a primary incentive for supply chain co-ordination and integration (Stock, Greis, & Kasarda, 1999). Streamlining supply chain logistics processes enhances the efficiency and effectiveness of supply chain management. In the current business climate, logistics activities acting at the operational level that span firms' boundaries are viewed as one of the key sources of supply chain competitive advantage (Bowersox, Closs, & Cooper, 2002; Dyer, 1994). It is contended that integration between value chain partners at an operational level is the core of logistics practice (New & Payne, 1995). Integration is not only shaped by the physical structure of supply chain (such as number of nodes, channels and tiers) but also by the relational structure that is developed through formal (i.e. contractual relationships) and informal (i.e. inter-firm relationships) mechanisms (Claro, Hagelaar, & Omta, 2003; Klein, Rai, & Straub, 2007; Straub et al., 2004; Zheng et al., 2008). Patnayakuni, Rai, and Seth, (2006) considered the strategy, operations and marketing perspectives together, concluding that cooperative behaviour rather than antagonist relationships are better for managing supply chains. The crux of cooperative relationships is information sharing beyond transactional data to include firms' operations and performance measures (Lee, So, & Tang, 2000; Lejeune & Yakova, 2005). It has been proven that relational governance and virtual integration predict information visibility through which flexibility can be achieved leading to the competitive advantage of a supply chain (Wang & Wei, 2007).

The mechanism through which firms' can create and sustain competitive advantage is emphasised in the following section through the introduction of resource-based view as an appropriate theoretical perspective.

2.2.8 RBV and sustainable competitive advantage (SCA)

The resource-based view (RBV) is a model of firm performance that focuses on resources and capabilities controlled by a firm through which competitive advantage can be attained (Barney & Hesterly, 2006). RBV has gained prominent attention in the field of strategic management. The term was originally coined by Wernerfelt (1984), it was developed based on the theory that a firm's success is largely determined by the resources it owns and controls.

RBV researchers have used a variety of terms pertaining to a firm's resources, including capabilities (e.g. Ray & Barney, 2004; Teece, Pisano, & Shuen, 1997), competencies (e.g. Hamel & Prahalad, 1990), skills (e.g. Grant, 1991), strategic assets (e.g. Amit & Schoemaker, 1993), assets (e.g.Vaaland & Heide, 2007) and stocks (e.g. Capron & Hulland, 1999).

The principal contribution of the resource-based view is providing a theory for developing and sustaining competitive advantage. It commences with the assumption that resources that are imperfectly mobile and heterogeneously distributed across firms, lead to SCA. Gaining a competitive position permits firms to earn economic rent or above-average returns (Fahy, 2003). Different mechanisms result in resources' immobility and heterogeneity including path dependencies, social complexity, causal ambiguity and time diseconomies (Barney, 1991; Mata, Fuerst, & Barney, 1995; Teece et al., 1997). Resources that are able to generate and sustain a competitive advantage that accrue superior performance, are described as valuable (Mahoney & Pandian, 1992), rare (Barney, 1986), inimitable (Peteraf, 1993) and non-substitutable (Dierickx & Cool, 1989) (referred to as VRIN).

It is acknowledged that some authors have criticised RBV as a value-creating strategy for competitive advantage based on the VRIN criteria. The main criticism made by Priem and Butler (2001) illustrated four aspects: RBV is self-verifying (tautological) as it is defined as a value creating strategy that is based on valuable resources; various resource configurations can yield a similar value for firms and therefore would not be CA; the product markets' role is less well articulated within RBV; and the limited perspective implications of the approach. Barney (2001) addressed counter-arguments to this criticism and concluded that RBV is a useful perspective of strategic management research. In addition, RBV is widely implemented in operations and supply chain research (e.g., Barratt & Oke, 2007; Lai, Li, Wang, & Zhao, 2008; Lewis et al., 2010).

2.2.9 Emerging RBV in IT research

The influence of IT on firm performance and in turn developing and sustaining competitive advantage, still requires more investigation. Firstly, although studies have confirmed the positive impact of IT on firm's performance (e.g. Hitt & Brynjolfsson, 1996; Palmer & Markus, 2000; Quan, Hu, & Hart, 2003; Thatcher & Oliver, 2001), the underlying mechanisms through which IT predicts firm performance, remain under examination in both information systems (IS) and management literature (Bharadwaj, 2000). In considering RBV, previous studies have investigated the relationship between IS and firm performance at an aggregated level and have attempted to quantify the managerial effects of IT investments on firm’s productivity, profitability and consumer surplus (e.g. Ravichandran & Lertwongsatien, 2005). Limited studies have focused on the impact of IT on the performance of business processes (Ray & Barney, 2004). Secondly, the underlying theories of explaining why and how IT innovations contribute to firm performance have gone through a paradigm change creating a need for finding a suitable paradigm or theoretical framework through which proper explanation can be made (Ravichandran & Lertwongsatien, 2005).

The most dominant theory influencing information systems researchers was the structure-conduct-performance model of industrial organisational economics. This model seeks to assess environmental threats and opportunities as external factors. The model has been discredited due to its limitation and weaknesses that implies the use of static analysis, the wrong level of analysis, and a foundation on barriers to entry as determinant of profitability (McWilliams & Smart, 1993). Researchers have argued that RBV with its focus on firm resources and capabilities provides an appropriate theoretical framework to examine how the internal factors of the firm rather than external ones can be source of competitive advantage. The resource-based view of the firm has already made an important contribution to the field of strategic management and it greatly enhances the understanding of the nature and the determinants of SCA (Fahy, 2003).

2.2.10 ERBV and SCA

According to the original assumptions of RBV, firms are considered independent entities, with each firm having full control of its resources. This logic is limited to examining only an individual firm perspective as it provides only a partial account of firm performance, overlooking the network or supply chain perspective i.e. the proliferation of inter-firm relationships and IOS (Lavie, 2006).

Extended Resource-Based View (ERBV) is an updated version of the original RBV concept that draws on how resources spanning firms' boundaries can be source of SCA (Lewis et al., 2010). Drawing on a review of the literature, ERBV combines both an economic perspective (Mathews, 2003) and a relational perspective (Dyer & Singh, 1998). Relying on ERBV and the relational view (RV), firms linked in a value chain are able to draw on a wide range of external resources through market-mediated transactions, various kinds of resource exchange and resource leverage relationships (Dyer & Singh, 1998; Lavie, 2006; Mathews, 2003).

Within ERBV, there is no representative firm, as firms linked in a value chain are the basic driving entities in ERBV and are differentiated based on their activities, which complement each other. In relation to complementarities logic, the interactions between firms linked in a value chain underpin collaborative behaviour rather than adversarial behaviour. Here, the heterogeneity factor is developed through the distinctive endowments or capabilities of inter-firm resources, and the dynamics through which these capabilities may be changed i.e. extended, shared or contracted. These dynamics are shaped through the interaction routines over time between supply chain partners (Mathews, 2003). Within ERBV, firms are able to access further resources through the virtue of their relationships with other firms in a value chain. According to ERBV, variation in firms' interaction routines can generate selective and distinctive dynamics between firms and across supply chains. These dynamics are concerned with a firms' ability to vary their activities and to engage in resource-sharing and resource-extending behaviour through inter-firm relationship mechanisms that can generate and sustain a competitive advantage.

In their study aimed at analysing the mechanisms through which original RBV and ERBV generate and sustain competitive advantage, Lewis et al., (2010) concluded that compared to RBV as originally conceived, ERBV focused on inter-firm resources would have more influence on creating and sustaining a competitive position and that integration between the two views would be required for long-term sustainable advantage.

2.2.11 Theoretical foundation of supply chain competitive advantage

Creating a competitive advantage is influenced by firm-specific capabilities shaped through exploiting their internal and external capabilities (Penrose, 1959; Wernerfelt, 1984). The mechanisms through which firms can create capabilities and renew their competences still need more investigation specifically within the context of SCM (Teece et al., 1997). It is stated that '*dynamic capabilities'* are the key source of enhancing performance and attaining and maintaining competitive advantage (Teece et al., 1997). *Capabilities* are referred to as firm's ability to adapt, reconfigure, and integrate internal and external resources as well as organisational and functional skills whilst *dynamics* indicate the firm's ability to renew its competences to adjust with current and expected changes in business environment (Teece et al., 1997). Enhanced performance is the outcome of capabilities and competitive advantage is the result of competences.

Attaining competitive advantage in the context of supply chain moves us from considering the internal scope of a firm's resources and capabilities, towards considering a firm's external resources and capabilities. Because of the interdependency between firms in a value chain and the considerable revolution in ICT and IOS resulting in information capabilities, firms cannot be isolated entities when planning their business strategies. The main assumptions of the original RBV are still valid within the internal firm's perspective. However, with respect to the supply chain context, and therefore including inter-firm relationships, RBV is limited analytical approach.

Until the mid 1980s, supply chains were mainly portrayed as managed through arm's length relationships to avoid externalities and opportunistic behaviours under the context of transaction cost economics (TCE) and, based on market prices through which enhanced performance could be attained (Hoyt & Huq, 2000; Patnayakuni et al., 2006). In the mid 1990s, different forms of relationships based on co-operation and partnership attracted academic and practitioner attention by means of managing supply chains. The supply chain and logistics literature reported the emergence of new competitive structures driven by the value chain perspective and based on inter-firm relationship mechanisms and network dynamics (Christopher & Juttner, 2000; Dyer & Singh, 1998). The inherent emphasis in this new trend was on competition between production and distribution networks i.e. value chains, not individual firms (Dyer, 1994; Ross, 1998). This, in turn revealed the importance of managing resources and capabilities across the extended enterprises (Dyer, 1994). Therefore, firms could gain benefits from being a member of a co-operative network. As such, as an extension of RBV, ERBV is more applicable when dealing with supply chain relationships as a key source for gaining competitive advantage (Dyer & Singh, 1998). This emerging perspective on SCM raised renewed questions about the relevance of transaction cost theory (Ghoshal & Moran, 1996).

The crux of ERBV is that firms that can combine their resources in a unique way may gain an advantage over competing firms unable to do so (Dyer & Singh, 1998). Hence, idiosyncratic inter-firm relationships may be a source of both relational rents and competitive advantage. Relational rent is a supernormal profit produced jointly in an exchange relationship. Relational antecedents for supply chain partnership include inter-firm interaction routines, partner-specific investment in dedicated assets and long term relational orientation (Patnayakuni et al., 2006). Dyer and Singh (1998) summarise the instances of attaining competitive advantage through inter-firm relationships; investment in inter-firm specific relational assets; exchange substantial knowledge; joint creation of distinctive capabilities through combining scarce complementary resources; and more effective governance relationships.

2.2.12 Evaluating SC competitive advantage

Porter, (1985a) describes two key types of competitive strategies: *cost leadership* and *differentiation* that might vary in their scope i.e. whether a firm seeks competition within the industry or within a specific segment. The cost leadership strategy aims at cost reduction, while flexibility, quality, delivery speed and reliability are related to differentiation strategy. Another dimension for competitive strategies is innovation, whether in terms of adopting new technologies, or developing novel ways of doing things (McGrath, Tsai, Venkataraman, & MacMillan, 1996). Competing at the level of the supply chain, not firm (Jap, 2001; Ross, 1998) requires establishing mechanisms of co-ordination and integration on different levels between supply chain trading partners (Patnayakuni et al., 2006). Hence, competitive advantage can be created through attaining overall customer satisfaction and economic values for all firms linked in a value chain that exceeds that of their competitor chains (Porter, 1985b; Straub et al., 2004).

The main aspects of enhancing supply chain competitive advantage include reducing the cost of customer service (Jones & Riley, 1985), improving customer service through reducing order cycle time and increasing the availability of stock (Cooper & Ellram, 1993), developing innovative solutions (Ross, 1998), cost reduction and service differentiation (Cooper et al., 1997; Tyndall et al., 1998). Therefore, creating supply chain competitive advantage is concerned with improving both *supply chain efficiency* e.g. cost reduction and *supply chain effectiveness* e.g. customer value and satisfaction. There are two main dimensions of measuring supply chain performance: Short term and long term. Tan, Kannan and Handfield (1998) state that *short term goals* of supply chain performance are related to enhancing productivity and reducing inventory and cycle time, whilst *long term goals* are related to increasing market share and profit for all supply chain members. The criteria that are used for both dimensions focus on financial and market measures; such as return on investment (ROI), the growth of ROI, market share, the growth of market share, profit margin on sales, the growth of sales, and the overall competitive position (Li et al., 2006a; Vickery, Calantone, & Droge, 1999) Firm's competitive advantage can be gauged through comparing these measures to firm's rivals or the industry average. For the purpose of measuring supply chain competitive advantage, aggregated measures are required i.e. assessing these measures for all firms linked in a value chain and then calculating the average value representing the competitive position of a specified supply chain (Straub et al., 2004).

2.3. Visibility and SCM

The previous sections illustrated the importance of inter-firm relationships in managing today's supply chains and how IT applications facilitate communications and co-ordination between firms linked in a value chain. This section provides an overview of supply chain visibility and its significance with a special focus on asset visibility.

2.3.1 Supply chain visibility (SCV)

Visibility is the outcome of information sharing supported by both relational governance and virtual integration (Barratt & Oke, 2007; Wang & Wei, 2007). Although supply chain visibility has become a buzzword in supply chain literature, its concept is still vague and poorly understood (Barratt & Oke, 2007). The proliferation of the term visibility has been accompanied by an incremental trend toward adopting supply chain collaborative applications such as vendor managed inventory (VMI), collaborative planning forecasting and replenishment (CPFR), efficient consumer response (ECR), and Radio frequency identification device (RFID) (Angeles, 2005; Barratt & Oliveira, 2001; Fliedner, 2003). Table 2-2 provides an overview of the development of supply chain collaborative technologies. These applications along with ICT represent the IT infrastructure for attaining supply chain visibility. Besides, within the supply chain literature, there is no commonly agreed definition for supply chain visibility (Francis, 2008; Zhang et al., 2008). The literature suggests different perspectives when defining supply chain visibility. Adopting an IT perspective, the council of supply chain management professionals (2006) define supply chain visibility as "*the ability to access or view pertinent data or information as it relates to logistics and the supply chain regardless of the point in the chain where the data exists*". In their work, Caridi, Crippa, Perego, Sianesi and Tumino (2009) classify SCV definitions twofold: information exchange and the properties of the exchanged information. *Information exchange* refers to information sharing between supply chain partners (Lamming, Caldwell, Harrison, & Phillips, 2001; Schoenthaler, 2003; Swaminathan & Tayur, 2003). On the other hand, the *properties of exchanged information* means the quality of information i.e. being accurate, readily available, trusted, useful, etc. (Closs, Goldsby, & Clinton, 1997; Gustin, Daugherty, & Stank, 1995; Schoenthaler, 2003).

From a logistics perspective, SCV means a transparent view of place, time, status and content (Fontanella, 2007). In his work, Francis (2008) drew on various supply chain visibility definitions and then developed his definition adopting an *event management perspective*. According to his definition, "supply chain visibility is the identity, location, and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates or times for these events*".* This study revisits the aforementioned definitions and concludes that some visibility definitions are more comprehensive as they consider various types of supply chain information whether concerned with physical or non-physical objects. Other definitions have targeted specific types of information which relate to physical movable objects or assets within a product supply chain context. Hence, it can be deduced that asset visibility associated with physical flow is a key component of supply chain visibility and will impact on financial and information flows.

In considering the asset visibility concept, some of the literature adopted a supply chain visibility definition to indicate asset visibility and vice versa (e.g. Francis, 2008; Johansson & Hellström, 2007). Consequently, there is an overlap between the two concepts.

Table 2-2: Collaborative technology in SCM

Type	**TOP***	**VMI/CRP**	**CPFR**	**RFID**
Evolution	***Before 1990***	***1990***	***2000***	***2005***
Information exchanged	Orders' information and dispatch advices	-Orders -Suggestive orders -Inventory report including store orders and warehouse shipments in CRP	-Orders -Inventory reports -Point of sale (POS) data -Sales forecasts -Promotion planning	-Product characteristics -Out of shelf products -Product position -POS data -History of product -Inventory information e.g. expiration dates -Back room inventory
Related-business processes	Replenishment	Central warehouse replenishment	-Central warehouse replenishment -Store replenishment -Promotion planning	-Replenishment -Reverse logistics -Legal compliance -Anti-counterfeiting -Product recall -Shelf management -Cold chain monitoring -Promotion management

Supporting technology for information exchange (IOS technology)	Paper; Electronic data interchange (EDI); EDI over internet; Internet based intermediary	Mainly EDI; EDI over Internet; Internet based intermediary;	XML files over internet; Global data synchronisation network GDSN (*expected*)	XML files over internet (*expected*); Electronic product code (EPC) network; Object name service (ONS) infrastructure *(expected*); GDSN *(expected).*
Supporting technology for user interaction	Internal enterprise resource planning (ERP) systems	Mainly internal applications; Lately collaborative platform- retail exchange	Collaborative platform- retail exchange	*Expected*: distributed application environment- web services *Expected:* collaborative platform- retail exchange.

Source: Adapted from (Pramatari, 2007)**.**
(*) TOP denoted to traditional ordering process.

2.3.2 Significance of supply chain visibility

Collaboration between supply chain partners may occur when "two or more share the responsibility of exchanging common planning, management, execution and performance measurement information" (Anthony, 2000). Drawing on figure 2-2 (the shaded parts refers to the area of the research focus), various supply chain processes create various types and massive volumes of data that need managerial attention to become useful information (Introna, 1991). This information needs to be visible i.e. communicated, so that business decisions can be informed. Collaborative information systems and information technologies are the key facilitator for information visibility between supply chain trading partners (Evernden & Evernden, 2003). Supply chain visibility in terms of information sharing and information quality is crucial in the decision making process that in turn, influences firm performance and overall supply chain performance (Swaminathan & Tayur, 2003). To re-iterate, above-average performance is able to create competitive advantage, which if maintained over time, generates SCA.

The delivery process has become one of the most influential factors in managing supply chains due to the pressure of on time delivery as a competitive differentiator between firms and among supply chains (Handfield & Pannesi, 1995; Stalk, 1988; Yusuf et al., 2004). Thus, real-time systems and responsive supply chains are substantial strategies for business survival and continuity (Chopra & Meindl, 2007). Some writers advocate the idea that information can be substituted for unnecessary inventory which is itself a barrier to achieving high responsiveness and cost reduction (Dudley & Lasserre, 1989; La Londe, Cooper, & Noordeweier, 1988; Li & O'Brien, 1999; Stock, 1990). Visibility positively influences near real-time activities, cost reduction, error reduction and streamlining supply chain activities. Transparent internal and external logistics processes are important factors for supply chain integration, specifically on the operational level enhancing supply chain performance (Bowersox & Daugherty, 1995; Loebbecke & Powell, 1998; Rai, Patnayakuni, & Seth, 2006). This transparency might create and maintain a competitive position, which is why the following section focuses on the asset visibility concept within a supply chain.

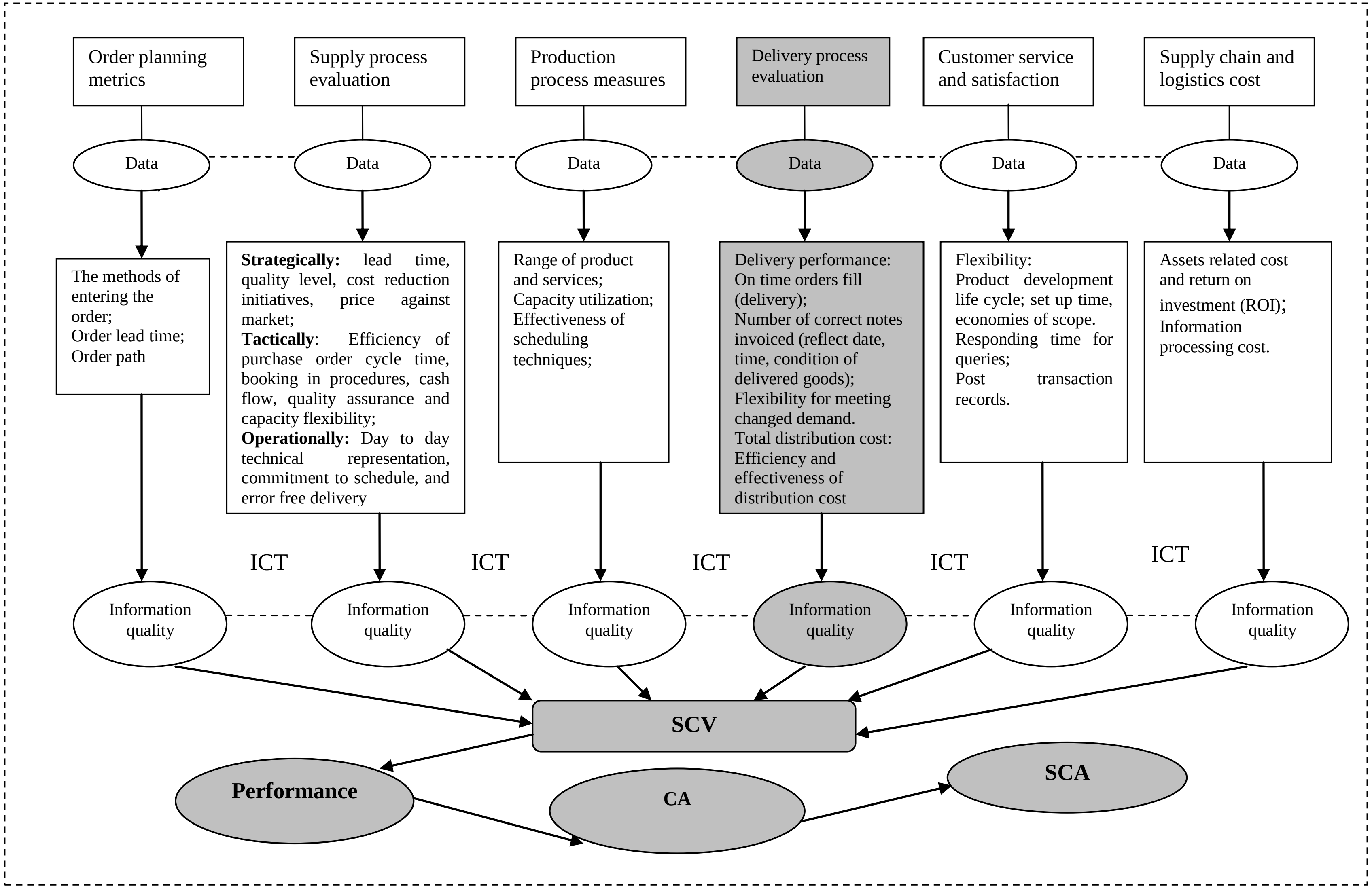

Figure 2-2: **SCV, performance, and SCA**
Source: Adapted from (Gunasekaran, Patel, & McGaughey, 2004).

2.4. Asset visibility within a SCM context

This section introduces the concepts of asset visibility associated with asset management systems within a SCM context. The significance of asset visibility specifically at an RTA level is presented. An overview on asset management systems is then introduced. This section draws also on the visibility gap associated with current asset management systems.

2.4.1 Asset visibility

Supply chain visibility is the aggregated outcome of information sharing using the IT infrastructure for supply chain integration (Swaminathan & Tayur, 2003). Asset visibility as a key pillar of product-based supply chain visibility; is the outcome of information sharing on an operational level, mainly concerning physical flows and relying on asset tracking applications to generate this information. Asset tracking is about using tracking applications to timely capture information about an asset's identity, location and status. Asset visibility can be attained when this information is available and can be accessed by supply chain partners. Drawing on the aforementioned supply chain visibility definitions, the asset visibility concept fits well within Fontanella and Francis' definitions (2007; 2008) that adopt the logistics and event management perspectives. This study considers asset visibility as an essential step towards better supply chain visibility.

This study treats visibility as a supply chain significant resource that constitutes the output of sharing business process information (Barratt & Oke, 2007). To explore the main capabilities beyond supply chain visibility, Barratt and Oke (2007) adopted an information sharing perspective in defining visibility to distinguish between *technological* and *non-technological* capabilities. Achieving visibility requires a combination of both capabilities. In a product supply chain, having asset visibility is the starting point to obtaining overall supply chain visibility. The basic unit of managing and controlling the physical flow focused on here is through the study of returnable transport assets (RTAs). RTAs may include pallets, pallet collars, crates, roll cages, barrels, trays, racks, boxes, trolleys, totes, lids and gas containers or refillable liquid (ISO, 2005). RTAs refer to *"all the means of assembling goods for transport, storage, handling and product protection in the supply chain returned for further usage"* (Thoroe, Melski, & Schumann, 2009). Visibility of these assets is seen as just as important as or even more important than product visibility (Johansson & Hellström, 2007).

RTAs' management systems can achieve visibility at the level of RTAs making each container or drum an external dynamic resource for attaining SCV. These systems require technological and non-technological capabilities. Flaherty (2007) as a practitioner argues that the use of information technology in managing RTAs is only a means to an end, not the end itself. Investing in new IT does not ensure competitive advantage, the capabilities that constitute the performance of this IT is of much greater consequence (Johnson, Klassen, Leenders, & Awaysheh, 2007). This research treats visibility of RTAs as the crux of product supply chain performance. The research takes as its starting point the view that tracking technology applications, specifically RFID as an advanced tracking technology, are an important factor in enhancing RTA visibility in supply environments of any significant complexity. The following section provides an insight on RTAs' visibility.

2.4.2 Significance of asset visibility

In considering the supply chain construct, Giannakis and Croom (2004) describe assets as exchanged items across a supply chain that can be classified as either static or dynamic. RTAs are seen as dynamic assets that have distinct characteristics compared to fixed assets. This entails different mechanisms for managing, tracking and maintaining RTAs.

RTAs management systems are typically more sophisticated, as they are utilised by multiple parties who play different roles across a supply chain. A firms' ability to manage their RTAs (the movement of products in forward supply chains and the return of empty RTAs in backward supply chains) can be key to their supply chain performance. RTA management directly affects response time, customer experience, order visibility, returnability, cost (inventory, transportation, facilities) and information availability (Chopra & Meindl, 2007). The main problem associated with RTAs is related to their loss due to customers' failure to return empty RTAs, thefts, or undocumented damage leading to supply chain disruption (Thoroe et al., 2009). Lampe and Strassner (2004) stated that typical problems in today's RTA management systems are the failure to identify and locate assets and to keep historical information about RTAs, resulting in poor visibility of these assets. Most current systems manage the number of assets in stock and cannot track individual assets. This may increase loss and theft and in turn cause unavailability of assets (Roh, Kunnathur, & Tarafdar, 2009). Additionally, these systems are not designed to record sufficient RTAs' data. Thus, many firms still have limited, timely visibility of significant processes engaged in global supply chain that may sub-optimise their performance.

In considering the structural changes in supply chain transport logistics, managing RTAs has become more influential and complicated. These changes include: (1) Reducing the number of suppliers with more robust relationships (O'Laughlin, Cooper, & Cabocel, 1993); (2) Demand for freight transport has transformed, focusing more on hub and spoke, and merge-in-transit, (Lemoine, 2004); (3) Increasing the trend towards outsourcing of logistics activities (Lemoine, 2004); and (4) Reconfiguring supply chains to be leaner in terms of the number of distribution facilities (Abrahamsson, 1998). According to these features, individual firm perspective in managing RTAs is no longer valid , SCM is the only appropriate lens for managing these assets. Figure 2-3 depicts the transformation from conventional flows of RTAs driven by an individual firm perspective to contemporary flows of RTAs driven by the SCM view.

RTAs facilitate the incremental trend towards lower transportation volume flows. In considering the efficiency of freight transport, RTAs allow economies of scale by the consolidation of a large number of shipments in batch flow units such as double stack train and cellular containerships (Hesse & Rodrigue, 2004).

RTAs can be a key enabler of the smooth flow of goods across supply chains (Ilic et al., 2009b). However, asset visibility is still a major challenge, specifically tracking RTAs remains a manual, error-prone process, resulting in high labour costs, asset shipping errors, manufacturing outages, incorrect orders and dissatisfied customers (Johansson & Hellström, 2007; Roussos, 2006).

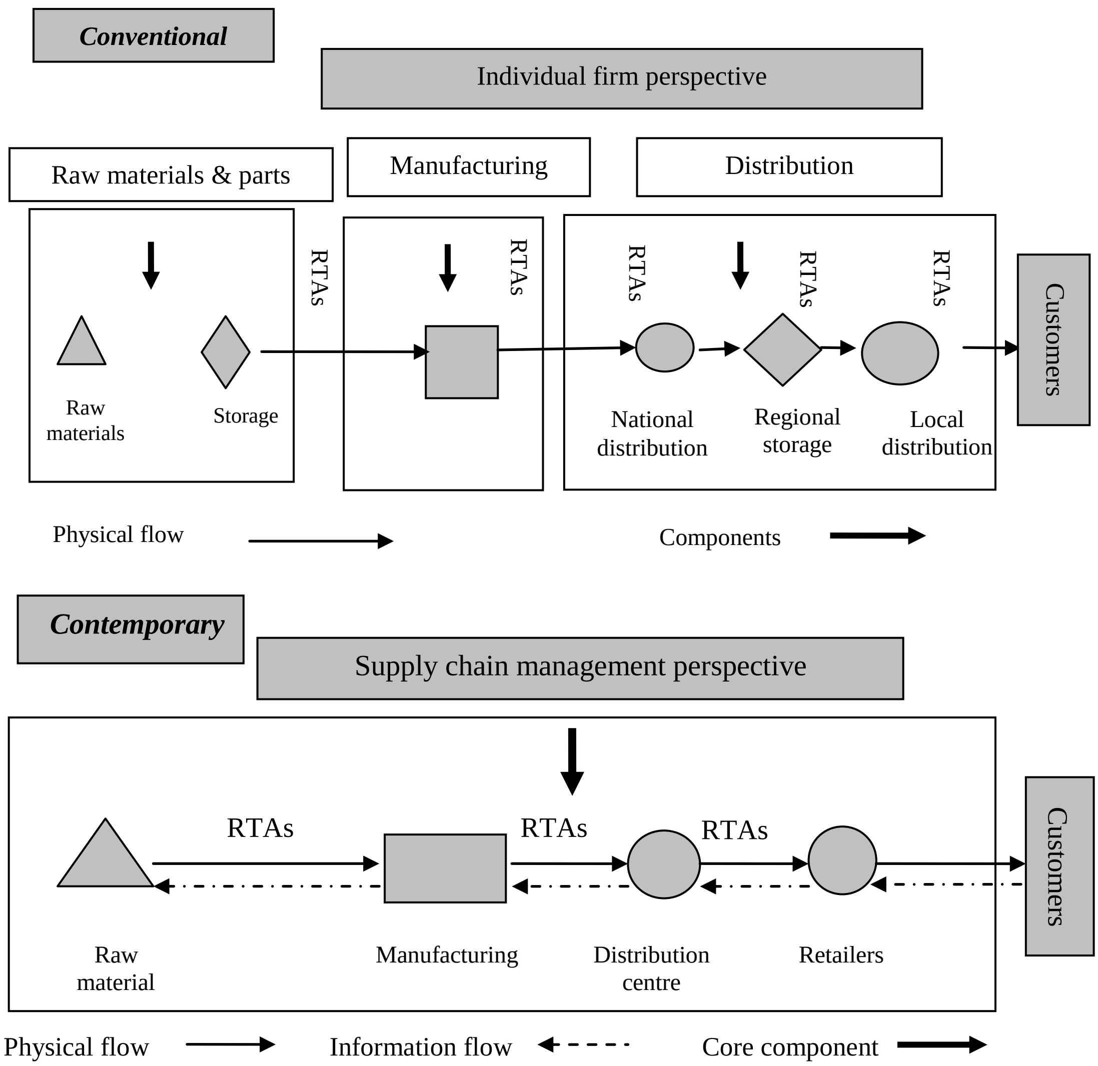

Figure 2-3: Conventional flow of RTAs vs. contemporary one across SCs
Source: Adapted from (Hesse & Rodrigue, 2004).

With reference to environmental concerns and carbon footprints, there are external forces pressuring firms to reuse and efficiently manage RTAs; government legislation adds to the commercial perspective as a new driver for enhancing current asset management practices (Bowman, Ng, Harrison, & Ilic, June 2009; Wu & Dunn, 1995).

This research claims that, with the emergence of RFID, accompanied by increasingly complex supply chain activities, RTAs have started to take a more strategic role in enhancing supply chain visibility. This new role requires developing understanding for the associated technological and non-technological capabilities, influencing visibility. The following section provides an overview of asset management systems.

2.4.3 Asset management systems: an overview

There are two models of managing RTAs: closed-loop model (also called the exchange model) and open-loop model (also called pooling model) (Bowman et al., June 2009). *Closed-loop pattern* refers to the simplest model which is based on exchanging or swapping the number of loaded RTAs for an equal number of empty RTAs. In closed-loop model, RTAs are exchanged between two members, e.g. the manufacturer and customers. This model fits more manufacturers who have their own customised RTAs or where suppliers own the RTAs. On the other hand, in the *open-loop or pooling model* the pool organiser or operator owns the RTAs and is responsible for confirming that the quantity and the quality of RTAs match the requirement of supply chain members. These RTAs are circulated between a number of senders (i.e. supplier, manufacturer, 3PL) and customers. The pooling model entails managing RTAs forward to the consignee's place and backward from the current delivery point to the next sender after performing any maintenance or reconditioning process. The pooling model is built on renting RTAs.

The pooling model is the predominant pattern in today's supply chain that is characterised by complex logistics operations in terms of high number of nodes and wide geographic reach. The exchange model can be seen as a special case of the larger pooling model that fits more with in-house supply chains (Bowman et al., June 2009). The main purpose of managing RTAs is to ensure continuous availability thus avoiding stoppages and shrinkage problems across a supply chain. Figure 2-4 depicts a generic view of the physical flow of open-loop or pooling model of RTAs throughout a logistics network. The figure also shows the supply chain trading partners involved in the physical flow of the RTAs: the supplier of new RTAs, the pooling operator, manufacturer, the distribution centre, retailers, third party logistics providers and a maintenance centre (Bowman et al., June 2009). In addition, the figure illustrates the routing of RTAs in two different logistics service options i.e. in-house service versus outsourcing.

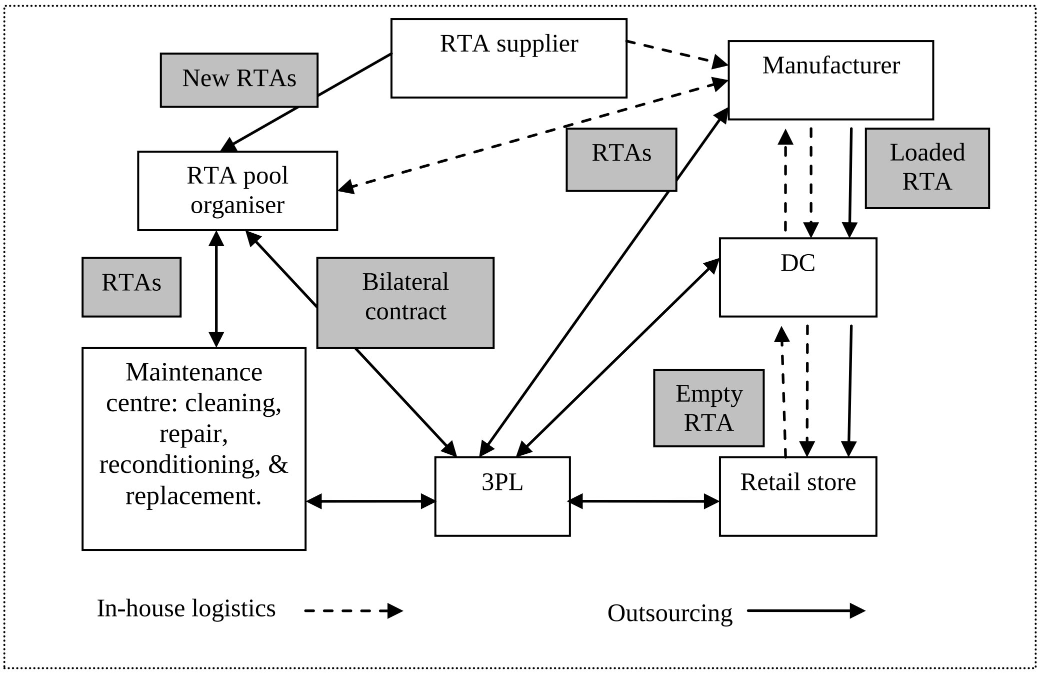

Figure 2-4: RTAM system across supply chains

Source: Adapted from (De Jonge, 2004).

Drawing on the logic of returnable transport asset management system, the study defines returnable transport asset management *as a systematic process of tracking and tracing both closed-loop and open-loop assets along the supply chain in order to enhance the supply chain performance and to maximise assets availability and reliability over their lifecycle at effective cost.* The study demonstrates that tracking and tracing**,** is the ability to determine at any point across a supply chain, the current and the past status of assets i.e. its identity, location, physical and operational status. The following table provides detail on the role of each participant in an RTAM system.

Table 2-3: The role of each participant in RTAM

Participant	***Role***
Supplier of new RTAs	Provides new RTAs to replenish or increase their stocks across a supply chain.
Pooling organiser	Handles empty RTAs; May own a number of distribution centres.
Manufacturer	Receives empty RTAs that entails loading and shipping them to their destination in a logistic chain, A reasonable buffer stock of empty RTAs is needed to meet the production schedule, yet unjustifiable large stock means accruing higher costs that should be avoided. RTAs are expected to be at the end of production line. Prior to this point RTAs are not in the logistic chain.

	RTAs that are warehoused carrying stock incur cost to manufacturer as they are out of RTAs loop in a supply chain.
Distribution centre	Receives loaded RTAs from many senders (suppliers or manufacturers) that entails unloading received RTAs, consolidating these loads with other loads, reloading consolidated loads and handling RTAs to be ready for re-shipping to their final destinations (this system called cross-docking); Buffer stock of RTAs should be maintained especially when contents of received RTA need to be split across two or more RTAs for forward distribution.
Retailers	Receives inbound RTAs that entail unloading and other receipt procedures; Received RTAs come from various sources that need to be emptied, sorted out, stored for later collection and quickly returned; Certain types of RTAs may be used as display units for products that are stored within the outlet for some time, e.g. shelf ready unit or stack of pallets.
3PL	Transports empty and loaded RTAs between supply chain nodes or members. Might provide extra services (e.g. warehousing or packaging). Needs arrangements with its supply chain trading partners related to shipping requirements.
Maintenance centre	Deals only with empty RTAs. Provide maintenance service including repair, cleaning and servicing of RTAs.

Source: Adapted from (Bowman et al., June 2009; Ilic, Andersen, & Michahelles, 2009a).

2.4.4 Asset management and the visibility gap

An RTAM system covers two dimensions, forward and reverse logistics supply chain (see figure 2-5). Unlike the relatively linear path of non returnable containers, the reusable nature of RTAs creates a cyclical or continuous flow across a supply chain (Bowman et al., June 2009). The forward flow of RTAs represents the actual progress of the order. If tracking and tracing procedures for RTAs are established, managing and controlling the physical flow of goods can be put in place (Jansen & Krabs, 1999).

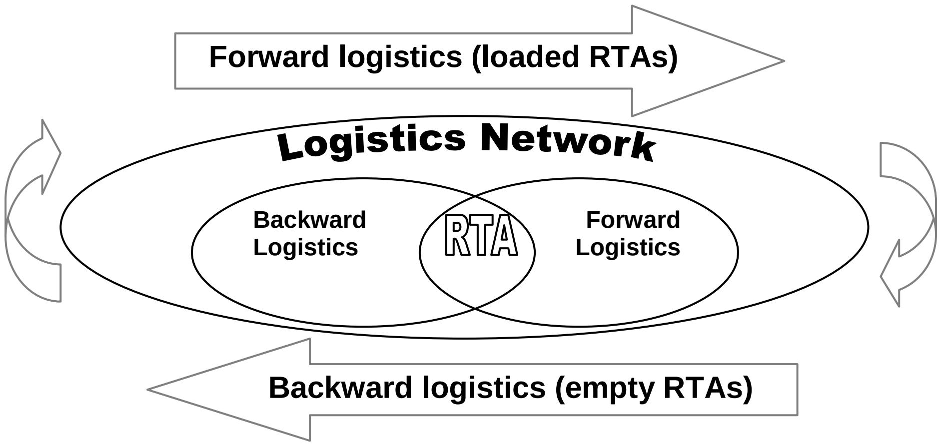

Figure 2-5: RTAs across logistics network

Jansen and Krabs (1999) argue that in recent years many firms have built up their logistics networks based on the use of multi-way returnable transport assets. However, the networks entail several problems associated with managing these assets, among which, the foremost issue is the implementation of effective redistribution structures implying ineffective asset tracking and tracing practices. These poor practices result in poor asset visibility.

The return of RTAs has a significant impact on supply chain performance. The impact of poor visibility of the returned assets is mainly related to losses due to damage, theft and misplacement. This problem leads to unavailability of these assets. Hence, many stoppages along logistics chains are encountered leading to higher logistics costs and dissatisfied customers. As such, the key objective of better managing the return of RTAs is to guarantee sustaining and streamlining outbound logistics activities. Besides, RTAs represent a considerable investment for the 3PLs or the pool organisers as they are associated with substantial costs e.g. rent, maintenance and replacement. The complete loss of RTAs incurs replacement costs, a serious issue across several industry sectors in UK (Breen, 2006). It is estimated that less than 20% of today's RTAM system use reliable and innovative data capture technologies, so that more than 80% of current RTAM systems are still managed manually or are barcode-based (Wamba & Chatfield, 2009). Asset management and specifically RTAM as an area of operations and supply chain academic research is under-researched (Breen, 2006); albeit practitioners contribute significantly to this area driven by the capabilities of innovative data capture technology such as RFID. The next section aims at developing the initial conceptual model of asset visibility capabilities influencing SCV and in turn firm performance.

2.5. Developing the initial conceptual model

This study seeks initially to address the knowledge gap related to supply chain visibility through track and trace technology. The study endeavours to investigate the capabilities associated with asset visibility, and how these capabilities might enhance overall supply chain visibility and firm performance. An initial model is created which will then be used to examine supply chain visibility, firm performance and SCA in unison.

This section draws first on the capabilities influencing visibility, followed by two sections focusing respectively on technological and non-technological capabilities that support visibility. The section culminates with an initial conceptual model.

2.5.1 Capabilities influencing visibility

This study treats visibility as a supply chain capability based on sharing business processes information. This interpretation builds on the idea that information visibility is the outcome of information sharing activities (Barratt & Oke, 2007; Swaminathan & Tayur, 2003). For the sake of exploring the main capabilities beyond asset visibility, the research adopts the aforementioned classification of visibility capabilities in terms of technological and non-technological as provided by Barratt and Oke, (2007) (see section 2.4.1, p.34).

To understand what type of capabilities may constitute visibility in a product supply chain, the research draws on the supply chain construct as earlier described. It is argued that supply chain researchers should work through an integrated construct that can lead to better understanding of supply chain problems and opportunities (Chen & Paulraj, 2004a). This construct should also be helpful in testing different theoretical frameworks, considering the relationships between different constructs and their influence on supply chain performance (Chen & Paulraj, 2004b). Hence, the main capabilities that may influence supply chain visibility should be reflected by such an integrated construct.

In their comprehensive structured review to develop a common supply chain management construct, Burgess, Singh and Koroglu (2006) conclude that the supply chain construct can be classified into a soft dimension i.e. a people-focused construct and a hard dimension i.e. a hard-system dominated construct. The *Soft construct* is related to social relationships including leadership and intra/inter-firm relationships. The *Hard construct* deals with technological and infrastructure issues including logistics, information systems, process improvement orientation and business results and outcomes. Giannakis and Croom (2004) categorised the supply chain field based on three strategic dimensions relating to: *synchronization dimension* representing the co-ordination and control of operations and logistics processes across the supply chain driven mainly by IT infrastructure; *synergy dimension* reflecting human interactions i.e. inter/intra-firm relationships; *and synthesis dimension* influencing the physical structure e.g. the scope of firm's vertical integration and distribution network.

Reflecting on these two constructs, the research now synthesises the literature reviewed thus far in this chapter. Visibility has become more significant in managing product supply chains mainly because of the incremental trend toward adopting information communication technology and collaborative supply chain applications supported by advances in tracking technology, that together constitute a hard construct representing the synchronisation dimension. This is accompanied by an incremental trend towards supply chain collaboration based on enhancing inter-firm relationships as a soft construct supported by intra-firm relationships that together reflect the synergy dimension. In addition, the contemporary features of logistics supply chains including cross-docking systems, shipments' consolidation, distribution centres and flexible routing (Hesse & Rodrigue, 2004) are a hard construct indicating the synthesis dimension may increase the significance of visibility.

This integrated perspective is represented in the following two sections through the differentiation between technological and non-technological capabilities influencing product supply chain visibility.

2.5.2 Technological capabilities

Based on literature review, section 2.3.1 proposed that IT is a key element and the primary enabler of supply chain visibility and that collaborative information systems and information technologies are the key to manage contemporary supply chains.

In the late 1990s, information has become an inter-firm resource supported by the development in collaborative supply chain applications and information communication technology (Evernden & Evernden, 2003). The emergence of the internet and web-based technology, e-commerce, enterprise resource planning (ERP), warehouse management system (WMS), transportation management system (TMS) and the increase in business-to-business applications, etc. are key enablers of supply chain visibility. These IT applications represent the technological infrastructure of supply chain physical, financial and information flow integration (Patnayakuni et al., 2006). In product-based supply chains, asset visibility, especially at the RTA level was almost unattainable without this infrastructure.

Tracking technology is the main enabler of asset visibility that is the key influential factor in enhancing product supply chain visibility. Traditional and obsolete manual tracking systems are considered a constraint for attaining asset visibility and in turn enhancing supply chain visibility. Tracking technology plays a key role in attaining visibility such as linear barcodes, two dimensions barcodes (2D barcodes), passive RFID and active RFID (New, 2010); albeit, various types of tracking technology influences different levels of visibility. RFID has distinct configurations compared to bar-coding system; linear barcodes have the minimal technological capabilities, whilst active RFID as has the highest capability; in between are the 2D barcodes. These technological capabilities are influenced by data capture criteria such as reading speed, the need of line of sight, human interaction, quantity of data storage, durability and reusability of data storage device (Asif & Mandviwalla, 2005).

RFID *is "a term that describes any system of identification wherein an electronic device that uses radio frequency or magnetic field variations to communicate is attached to an item"* (Dogra, Chatterjee, Ray, Ghosh, Bhattacharya, & Sarkar, 2010). Wyld (2006) and Glover and Bhatt (2006) indicted that RFID as a technological asset, consists of two main components, including hardware and software. The hardware infrastructure contains tags (transponders), antenna (used in both tags and readers), readers (interrogators) and printers. The software infrastructure includes tag's protocol, reader's protocol, and RFID middleware (event manager), that link the RFID components to larger information processing system (Wyld, 2006). Compared to barcodes, RFID, specifically active RFID as an innovative data capture technology has a number of advantages including: (1) non-human interaction; (2) automatic non-line of sight scanning; (3) high storage capacity of data; (4) simultaneous high speed reading; (5) high durability of reusable tags (Attaran, 2007; Want, 2006). These features influence high technological capabilities. The key limitations that might have a negative impact on RFID related capabilities are mainly associated with standardisation issues, reading technical and legislative considerations and privacy concerns (Glover & Bhatt, 2006).

RFID shows a positive impact on asset visibility and in turn on supply chain visibility. RFID has emerged as an advanced automatic identification technology and is expected to be the next big wave in supply chain (Bose & Pal, 2005). RFID as an example of supply chain collaborative application is predicted to revolutionise many supply chain processes e.g. warehousing, transport and distribution processes and inter-firm relationships (Prater, Frazier, & Reyes, 2005). Recent studies, (e.g. Martinez-Sala et al., 2009; Thoroe et al., 2009) have reported that the highest potential benefits associated with RFID can be attained when RFID tags are used with RTAs e.g. containers, kegs, pallets, boxes, etc. On this bulk shipping level, RFID has proven its concept in tracking RTAs. Delen, Hardgrave and Sharda (2007) assert that the main driver for applying RFID is to enhance process efficiency and it is expected to be one of the business process enablers. Practitioners and academic research highlighted the influence of this technology on collaboration between firms (Boeck & Wamba, 2008; Lekakos, 2007; Roberti, 2006). Roh, Kunnathur, and Tarafdar (2009) expect that with full deployment and integration of RFID, various business aspects can be integrated and well managed. However from an academic point of view, how RFID can play this role is still under-researched (Simchi-Levi, Synder, & Watson, 2002). Furthermore, recent studies indicate the positive impact of integrated tracking technology; mainly geographical positioning system (GPS) on information quality and sustainable competitive advantage e.g. (Bourlakis & Bourlakis, 2006; Schindler, 2003; Sellitto, Burgess, & Hawking, 2007).

Based on a review of the literature, how tracking technology, specifically RFID can influence asset visibility in a way that might enhance SCV leading to better performance remains vague (Simchi-Levi et al., 2002). In other words, the technological capabilities of RFID system that can enhance asset visibility within supply chain context is still under-researched.

2.5.3 Non- technological capabilities

Over the last two decades, supply chain management has become one of the major organisational practices as firms are electronically connected to their supply chain partners forming inter-organisational operations and relationships (Byrd & Davidson, 2003). As such, collaboration and transparency between supply chain partners have become the key strategies for managing current supply chains. Collaboration between supply chain partners means that "*two or more share the responsibility of exchanging common planning, management, execution and performance measurement information*" (Anthony, 2000). Supply chain managers have become willing to share more information and to explore new mechanisms for mutual benefits. These benefits are rarely perceived due to differences in interest, perceiving information disclosure as loss of power, mutual distrust and a tendency to local optimisation and opportunistic behaviour (Lejeune & Yakova, 2005).

Clemons and Row (1993) stated that co-ordination problems are related to *uncertainty* due to insufficient inter-firm information or inefficient information processing capacity. According to this view, better co-ordination enhances timeliness information transmitted throughout firms' boundaries.

Supply chain co-ordination and collaboration require investment in IT along with significant changes in the organisational mechanisms used to manage the interaction routines that is termed as *co-ordination structure* (Pramatari, 2007). Conceptually, improved co-ordination must be viewed not just in terms of players changing their strategies within an existing business game, but in terms of changing the structure of the game (Clemons & Row, 1993). As such, mutual trust, goal congruence and information sharing are seen as important mechanisms for supply chain co-ordination and collaboration (Lejeune & Yakova, 2005).

Collaboration and co-ordination are antecedents for effective supply chain integration that consider cross-functional process integration within the firm as a trigger for supply chain initiatives (Flynn et al., 2010). Supply chain integration is pertaining with both forward and backward integration across supply chain activities that can be translated in terms of physical, financial and information flows (Fawcett & Magnan, 2002). The degree of this integration might vary according to its functional scope e.g. purchasing, manufacturing and/or logistics. As such, the degree of this integration might influence the level of information sharing and in turn visibility. In current supply chains, information sharing reflects the progress of order not the actual flow of goods that negatively affects supply chain visibility and in turn affects decision making process ending with poor performance. Hence, physical flow integration that is directly related to transport logistics processes does not seem to be influential in gaining visibility compared to financial and other information flows. RTAs as basic physical units of this physical flow are substantial in attaining visibility on this level. The predominant model of managing RTAs is a pooling model in which different supply chain partners influence asset visibility including e.g. manufacturers, 3PLs, and retailers.

Drawing on a review of extant literature, how non-technological capabilities can influence asset visibility in a way that might result in enhanced SCV and in turn, performance remains under-researched. The following section provides the initial conceptual model that seeks to investigate asset visibility capabilities and their influence on SCV and performance.

2.5.4 Initial conceptual model of asset visibility, SCV and performance

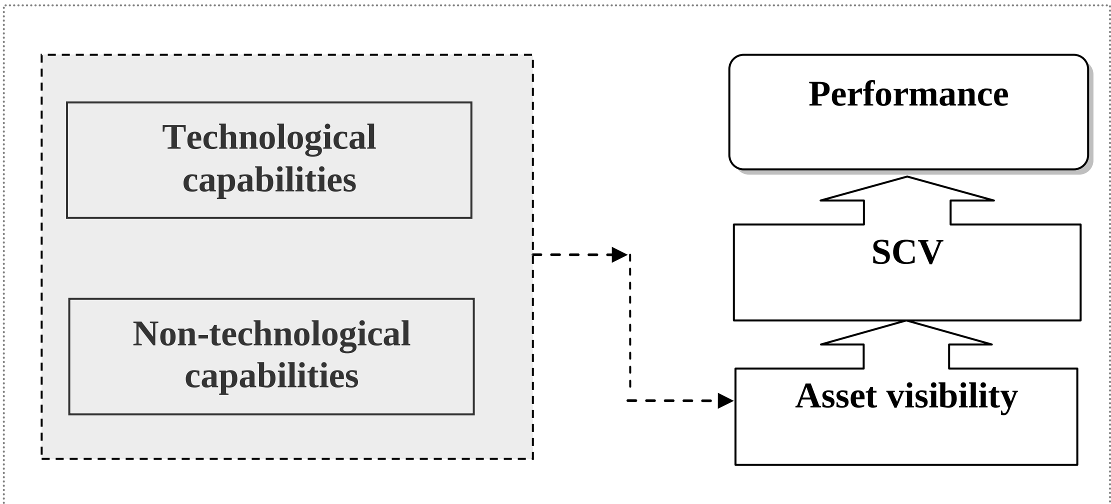

Figure 2-6: **Initial conceptual model**

Figure 2.6 depicts the initial conceptual model. The research argues that asset visibility capabilities that may predict SCV and firm performance are formed by both technological and non-technological aspects. The research contends that IT infrastructure for supply chain integration along with asset management systems using data capture technology constitutes the technological capabilities of asset visibility. The research also posits that non-technological capabilities of asset visibility are shaped by firms' interaction routines managed through internal and external relationships, especially those related to logistics activities.

2.6. Summary of the chapter

This chapter provided a theoretical base for developing the initial conceptual model for further empirical investigation to address the research questions. The chapter began with a theoretical background of supply chain management and its effect on firm performance and competitive advantage. RBV and ERBV were introduced as the research's theoretical perspective. In addition, supply chain visibility and asset visibility as the main focus of this research were discussed. In conclusion, the research's initial conceptual model was developed.

The following chapter provides a deep insight on the adopted philosophical and methodological stances through which the research objectives can be achieved.

Chapter 3: Research design

3.1 Introduction

This chapter is concerned with the transformation process from purely theoretical research into a philosophically and methodologically applicable research study. Research is a process of finding out information and investigating the unknown to solve a problem that may contribute towards the advancement of knowledge (Bassey, 1999; Maylor & Blackmon, 2005). Management research can only be understood as an applied field because it is conducted through understanding the nature of organisations and with through solving of problems that are related to managerial practices (Bryman & Bell, 2007). However, there are different approaches through which the research may be conducted**,** which in turn reflect both philosophical and practical stances. Figure (3-1) presents the main elements of research design.

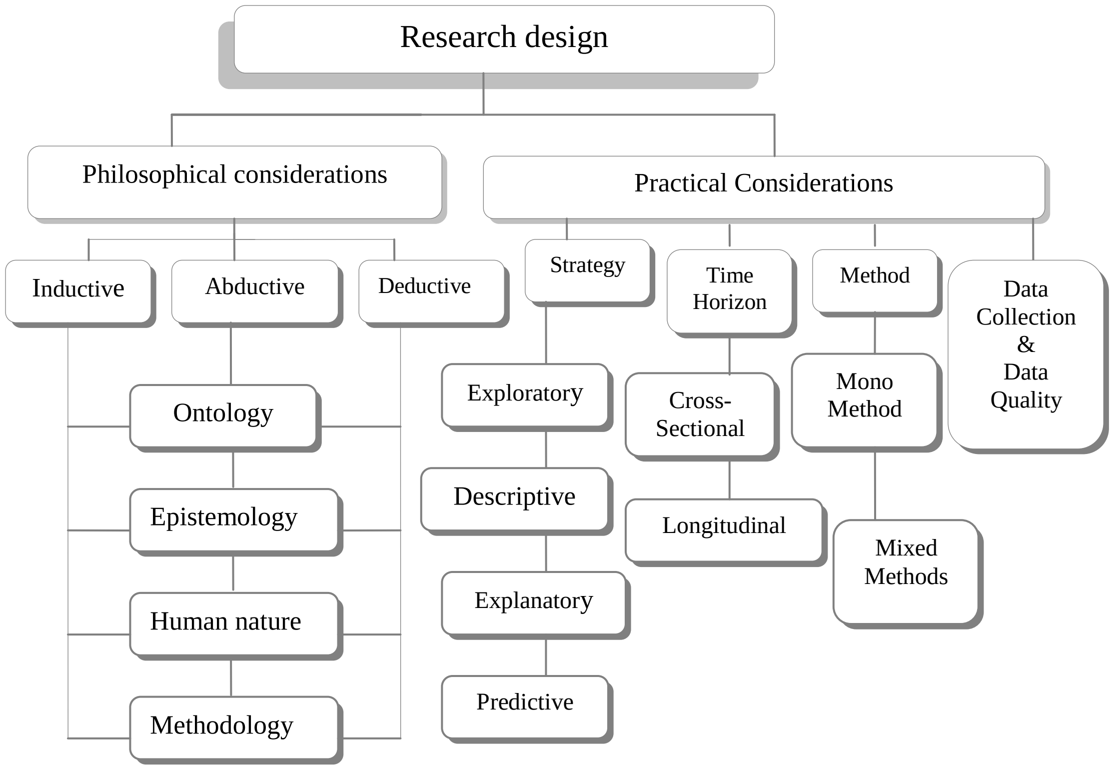

Figure 3-1: Research design

Source: Adapted from Bryman and Bell, (2007) and Saunders, Lewis, and Thornhill, (2007).

This chapter examines the different phases of research design, each of which entails various choices. The chapter is divided into two main sections. *The first section* discusses the philosophical implications of social research and includes the key philosophical assumptions adopted here, the paradigms explored, the research logic, the main approaches to social science and the adopted research approach. *The second section* is concerned with the practical considerations of social research that are associated with a chosen research strategy and time horizon. Based on the chosen strategy, mixed methods approach and data collection strategy are explained. Sampling decisions are made in the light of discussing sampling options that are followed by illustrating the unit of analysis. Data collection techniques are introduced and the related methodological decisions are made for the two phases of the research (pilot study and survey); data quality issues are clarified. Finally, the chapter ends with explaining the operationalisation process of the employed variables and a summary of the chapter. Figure 3-2 briefly depicts the structure of the chapter.

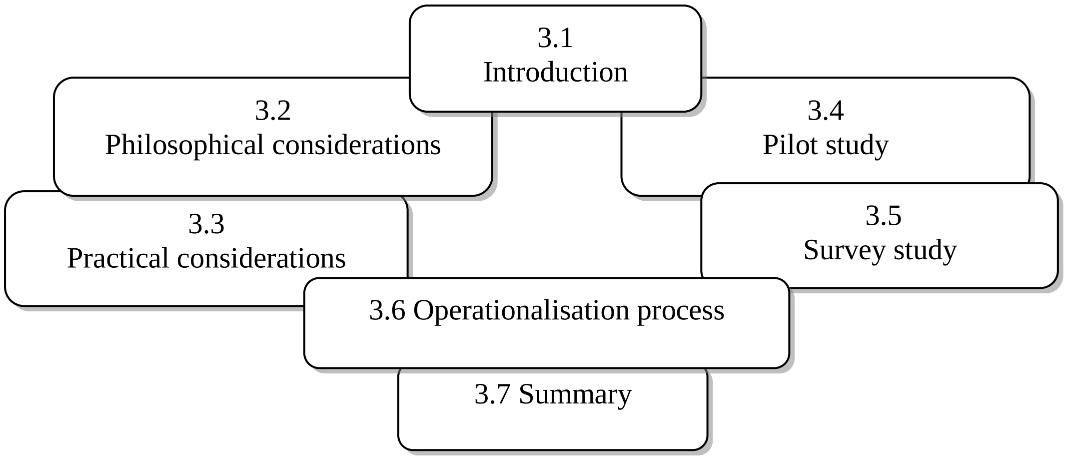

Figure 3-2: Structure of chapter three

3.2 Philosophical considerations of social research

Research paradigms is an idea made famous by Thomas Kuhn (1970). It refers to a general organising framework for theory and research. It includes a basic set of beliefs that guide human action and provides a philosophical basis for the research strategy (Denzin & Lincoln, 1998).

Social research is a collection of methods and methodologies that researchers apply systemically to produce scientifically based knowledge about the social world (Neuman, 2006). Burrell and Morgan (2000) present a comprehensive classification of social research that includes four key paradigms each of which has distinct philosophical assumptions about the nature of social science and the nature of society. Each paradigm is explained through a coherent view of the social world under the umbrella of subjective and objective stances. These four research paradigms are ontology, epistemology, human nature, and methodology. These philosophies are associated with the question of *how do people go about developing knowledge about their world?* (Briggs & Coleman, 2007).

3.2.1 Philosophical assumptions

"The confidence provided by understanding different philosophical positions provides the researcher and the practitioner with the power to argue for different research approaches and allows one confidently to choose one's own sphere of activity" (Dobson, 2002). Hence, the research draws on various philosophical considerations as a starting point through which the design of the research is decided. Burrell and Morgan's (2000) four philosophical assumptions that inform different social sciences approaches are presented in table 3-1. The next section examines each paradigm and their main arguments.

Table 3-1: Philosophical stances of the nature of social science

Philosophy	***Subjective nature***	***Objective nature***
Ontology	Nominalism	Realism
Epistemology	Anti-positivism	Positivism
Human nature	Voluntarism	Determinism
Methodology	Ideographic	Nomothetic

Source: Adapted from (Burrell & Morgan, 2000, P.3).

Ontology (Realism/Nominalism)

Here the concern is with *the nature of the reality of the phenomenon under investigation*. Ontological assumptions distinguish between two concepts; objectivism/realism and constructionism/nominalism. *The former concept* relates to an ontological assumption through which social phenomena and their meanings have an existence that is independent of social actors (Bryman & Bell, 2007). Hence, reality is external to individuals; i.e. reality has an *objective nature* (Burrell & Morgan, 2000). *The latter concept* is concerned with an alternative ontological stance that advocates that social phenomena and their meanings; i.e. that reality is continually accomplished by social actors (Bryman & Bell, 2007). It postulates that the social world external to an individual's cognition is made up of only names, concepts and labels that structure reality (Burrell & Morgan, 2000). Hence, reality is the product of individual consciousness; i.e. reality has a *subjective nature*.

Epistemology (positivism/anti-positivism)

Epistemology is interested in *what is regarded as an acceptable knowledge in a discipline i.e. what is known to be true* (Bryman & Bell, 2007). The main question here is whether or not the social world can be studied through the same knowledge (principles, rules, systems) as the natural sciences. Consequently, the assumptions of epistemology are related to what is known as positivism and anti-positivism.

Positivism is an epistemological stance that supports the application of natural sciences' methods to social research that emphasises discovering causal laws, careful empirical observations, and value free research (Bryman & Bell, 2007; Neuman, 2006). The *ontological assumption of positivism* is that reality of positivist research is external and has an objective nature. The *epistemological assumption of positivist* research is that knowledge is only of significance if it is based on observation of this external reality.

Gill and Johnson (2002) draw on the *criticisms for positivism* made by Laing (1967) as follows: 1) Human action has its own logic which must be considered in order to present a comprehensive interpretation of the action; 2) The logic of natural science does not imply the subjective perspective of human beings to understand the action, so that such methodology is inappropriate and insufficient; 3) the social world cannot be understood through causal law, so that human action is purposive and becomes explainable only when subjective quality is considered.

Anti-positivism (interpretivism) as an opposing assumption of positivism takes various forms and postulates that the social world is basically *relativisti*c and can only be understood from the point of view of the individuals involved in the activities investigated by the researcher (Burrell & Morgan, 2000). In this case, social science takes a *subjective stance*. It requires the researcher to comprehend the subjective meaning of social action. Hence the study of the social world requires a different logic of research procedure that reflects the distinctiveness of humans against the natural order (Bryman & Bell, 2007). Interpretivism tends to be nominalist (ontology), voluntarist (human nature), and ideographic (methodology), see the following two sections for more discussion.

Interpretivism is subject to a number of criticisms, some of which are related mainly to the approach in its purest form. Briggs and Coleman (2007) proffer criticism of the interpretivism approach in three key points. *Firstly*, reality could not be an achievable issue because it is seen from multi-perspectives and also because the way in which humans create meanings reflects what they do. *Secondly,* their argument is related to the unfamiliarity of humans to reflect in a structured manner upon their behaviour as behaviour is a routine process. *Thirdly,* research participants may be unaware of the broader structures that govern their interpretation. This happens because of the incomplete sense of humans' accounts of themselves, of others, and of events.

Human nature (Deterministic/Voluntarism)

This paradigm concerns the relationship between human beings and their environment. It is related to the behaviour of humans; i.e. how they respond to external forces. The way of responding is called the model of man. The *Deterministic model of man* sees man and his activities as being completely influenced by the situation or by his environment. In this case, human beings and their experiences are seen as products of the environment (Burrell & Morgan, 2000). Positivism emphasises deterministic relationships and looks to determining the causes of the mechanisms that produce effects (Neuman, 2006). *The main argument of the deterministic approach* is that positivism believes in absolute determinism, i.e. people are like robots or puppets who must always respond in the same way. The causal laws are probabilistic, so laws may help in making accurate predictions of the expected social behaviour in a large group. However, these laws cannot be expected to apply to the specific behaviour of a specific person within the group.

Another model of human nature is called *voluntarism.* The voluntarist perspective implies that man is completely autonomous and free-willed (Burrell & Morgan, 2000). Here man is regarded as the creator of his environment. Hence, human actions are based on the subjective choices and reasons of individuals. Since interpretivism emphasises voluntary individual free choices, this perspective is supported by the interpretivist approach (Neuman, 2006). *The main argument to voluntarism* is that external forces should have certain impacts on human behaviour. While social science theories are concerned with assimilating human activities, they should consider the intermediate viewpoint of both situational and voluntary elements when dealing with human beings' activities.

Methodology (Nomothetic/ Ideographic)

Methodology provides a rationale for the ways in which researchers conduct research activities (Briggs & Coleman, 2007). It is related to the best means of gathering knowledge about the world in terms of methods, techniques, or tools. Each paradigm of the previous three paradigms reflects a specific methodological nature through which knowledge can be investigated and obtained.

Burrell and Morgan (2000) differentiate between *nomothetic*[1] and *ideographic* views of social science. The former view is associated with applying systematic protocol and technique. The latter view stresses the significance of letting the nature and characteristics of one's subject be involved during the study.

Positivism interpretation is *nomothetic* in that it is based on a system of general laws. Researchers connect causal laws and observed facts about social life with deductive logic. The nomothetic view applies scientific methods[2] of natural science (Neuman, 2006).

Contrary to positivist conducted social science, the interpretivist approach is *ideographic* and inductive. The ideographic view provides a symbolic representation or detailed description of something with very limited abstraction (Neuman, 2006). Epistemological (positivism/anti-positivism) and methodological considerations are involved at each stage of the research process. Information collected by the researcher whether qualitative and/or quantitative, is transformed through the analysis into data and then into knowledge (Briggs & Coleman, 2007).

3.2.2 Pluralist of paradigms

Philosophically, researchers make claims about what is knowledge (ontology), how we know it (epistemology), what values go into it (axiology) and the processes of studying it (methodology) (Cotty, 1998; Creswell, 1994; Neuman, 2006). Paradigms as human constructions cannot be correct in all instances; persuasiveness and utility rather than

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[1] Nomos means law in Greek.

[2] Scientific method is the ideas, rules, techniques, and approaches that the scientific community uses to create and evaluate knowledge.

proof are the only way to advocate any particular construction in arguing a certain position (Denzin & Lincoln, 1998).

Robey (1996) argues that a diversity of research methods and paradigms within the discipline is a positive source of strength. This can be justified as diversity provides a wider range of knowledge which is crucial for research and theory. Yet, this plurality requires disciplined methodological pluralism to confirm the rationality of each paradigm.

There is no agreed way of defining different paradigms which is known as *paradigm incommensurability* (Mingers, 2001). Landry and Banville (1992) have presented two strong arguments for underpinning methodological pluralism. Their f*irst argument* is that the real world is ontologically stratified and differentiated, constructed of a plurality of structures which create the situations, each paradigm focuses on different aspects of the situation. Hence, a pluralist approach to research methods is essential for effective investigation of the complexity of the real world. Their s*econd* argument is that a research study is a process which includes a number of phases with different tasks and problems. Thus, combining various research methods is useful to achieve the objectives of each phase.

Rationale for pluralist of paradigms in this research

This research is interested mainly in investigating visibility in the context of supply chain management i.e. real world complexities. Given that the topic area here, supply visibility, is a relatively new concept where knowledge is still not well constructed in order to achieve the research objectives, an integrated multi-dimensional perspective is employed. To this end, adopting different methods that are able to examine both known and unknown data was deemed appropriate. Therefore, pluralism of paradigms and associated research methods is particularly important in this research.

3.2.3 Research logic

The logic of social research can be classified as deductive, inductive, or abductive. Table 3-2 depicts the main three features that can be used to differentiate between the three logics.

Table 3-2: Main features of the research logic

Research logic	***Starting point***	***Objective***	***Findings***
Deductive	Begins with a theoretical framework that can be the conclusions from inductive or abductive reasoning.	Testing theory	Deductively drawn through confirming or falsifying prior hypotheses constitute findings; -statistical generalisability
Inductive	Empirical observations	Developing theory	Inductively drawn based on empirical observation constituting findings; -Analytical generalisability
Abductive	May start with real-life observation and/or with pre-perceptions and theoretical knowledge	Developing theory through developing an understanding of a new phenomenon	Abductively drawn through suggesting hypotheses and the application of these hypotheses to the empirical research constitutes findings; -Relatively generalisable.

Source: Adapted from (Kova´cs & Spens, 2005).

Drawing on table 3-2, *deductive research* starts with a literature review to derive a logical understanding of a certain issue from the theory. The literature review is followed by developing hypotheses or propositions and testing these hypotheses in an empirical setting. Deductive research ends with a logical conclusion based on corroboration or falsification of hypotheses. Here, the logical sequence of a research process is from *rule to case to result* (Danermark, 2001). In considering *inductive researc*h, observations about the world lead to emerging propositions and their generalisation in a theoretical frame. The logical sequence of the research process is from *case to result to rule* (Danermark, 2001). Abduction research entails a combination of both deductive and inductive logic. The a*bductive* research process sequence is from *rule to result to case* (Danermark, 2001), see figure 3-3.

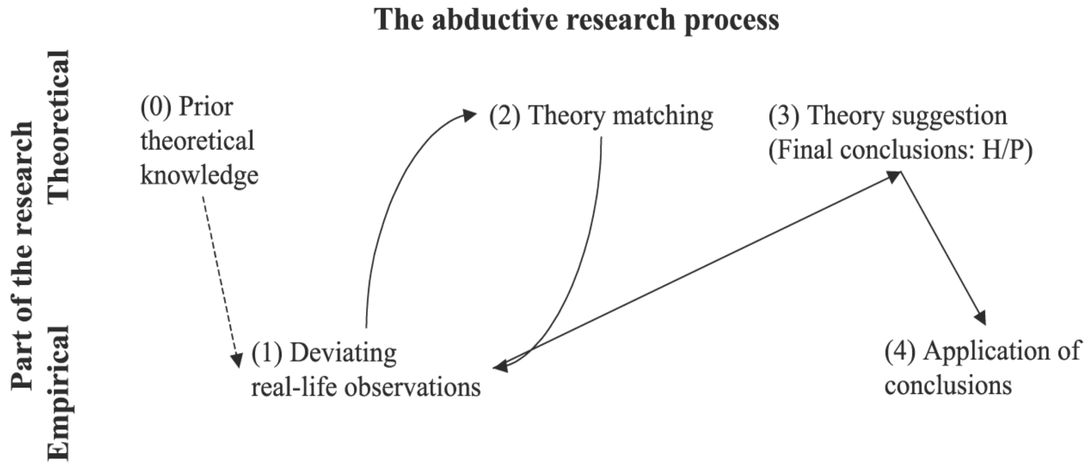

Figure 3-3: Abductive research process
Source: Kova´cs and Spens (2005).

Drawing on the abductive research process shown in figure 3-3, abductive research may start with empirical observations and/or theoretical knowledge with some pre-conceptions. It may lead to a conclusion that observation in an empirical setting does not match (deviated observation) these prior theories. Therefore, the creative iterative process (a theory matching) is required for matching an extended or new theoretical framework with anomaly observations. In abductive research, the researcher can also start with intuition or a creative element through adopting a new theory or a new conceptual framework to an already existing phenomena (Kirkeby, 1990). The key aim of abductive research is better understanding of a new phenomenon through developing hypotheses supported by existing theory and ending with the application of these hypotheses in an empirical setting.

Rationale for abductive logic in this research

This research participates in verifying the assumptions of ERBV as the key theoretical lens in this research and seeks to develop new knowledge in the area of supply chain management, specifically supply chain visibility. *Deductive positivism* seems to be a predominant approach in supply chain management research (Mentzer & Kahn, 1995; Na¨slund, 2002). This kind of research is most suitable for testing existing theories, not for developing new knowledge leading to new theories. Besides, Stock (1992), claims that logistics has been criticised for not having a rich heritage of theory building and suggests using more philosophy of science material for the sake of theory development in logistics. This study deals with asset visibility as an under-researched area within supply chain visibility that can be seen as part of logistics process.

In his work, Listou (1998) states that little logistics research has focused on theory development, mainly because of the predominance of the positivist approach in supply chain research. However, using different approaches that support building new knowledge is seen here as a must given a trend towards more complex supply chains, more collaboration and more technological orientation, all of which negatively impact visibility. Creating such new knowledge in an interdisciplinary field such as supply chain management then requires an *inductive logic*. Yet, because both deductive (positivist approach) and inductive (interpretivist approach) logics are limited to establishing already known constructs (Kirkeby, 1990), they may not be valid if they are individually employed to create such a new knowledge.

Abduction is systematised intuition in research to develop new knowledge (Andreewsky & Bourcier, 2000). This kind of intuition often comes from an unexpected observation that requires interpretation of an inconsistency, abnormality, or ambiguity that cannot be explained through an existing theory or knowledge. The dilemma of this ambiguity is augmented due to the complexity shaping current supply chains that consequently might influence visibility and performance. Undoubtedly, there is a need to develop a model that might combine these dimensions and which may lead to new knowledge within the constructs of supply chain management.

3.2.4 Key approaches for social science

There is a diversity of approaches related to what constitutes knowledge claims in social research. These approaches are intertwined with the various assumptions of different philosophies. The next table 3-3 presents positivism and interpretivism as the two key approaches in social science research[3]. The table also provides critical realism as an emergent approach for research in social science especially operations management research taking an intermediate position between positivism and interpretivism. These approaches are explained in the light of the main four paradigms.

[3] Three additional approaches are not likely to be used in this research which are critical theory and related ideologies, feminist, and post modern social science. These approaches criticise positivism and offer alternatives that build on interpretive and critical social science.

Table 3-3: Key approaches for social science

Factor	***Positivism***	***Interpretivism***	***Critical realism***
Research purpose	Discovering natural laws to predict and control events	Understanding and describing social situation	Developing better understanding of the enduring structures and mechanisms of reality
Objective	Explanatory	Exploratory	Mixed
Ontological stance	Reality is already existent and stable, ready to be discovered, Objective to human cognition	Relativism: no single point of view or value position is better than others; Subjective to human cognition.	Reality is "relatively enduring"; Reality is "real" but only imperfectly and probabilistically apprehensible; Triangulation is required to know it.
Epistemological stance (researcher's position)	Objectivism: the researcher is objective by viewing reality through a "one-way mirror" Dualism: the researcher and the object are independent entities	Transactional and subjectivism: the researcher is a "passionate participant" or interactively linked within the world being studied	Dualism cannot be maintained. Objectivism is still dominant; the researcher is value-aware and needs to triangulate any perceptions he or she is collecting.
Human nature	Deterministic	Voluntarism	Intermediate position
Methodology	Concerned with testing theory using quantitative Methods: experimental design and non experimental design e.g. survey, simulation modelling	Narrative Phenomenology Ethnography Grounded theory Case studies	Modified experimental/ manipulative methodology; Concerned with falsification of hypotheses using mixed methods e.g. surveys, case studies.
Research logic	Deductive	Inductive	Abductive
Nature of knowledge	Verified hypotheses established as facts or laws	Individual reconstructions coalescing around consensus	Non-falsified hypotheses that are probable facts or laws
Values	Value free	Values are integral part of social life	Value-aware
Methods	Purely quantitative	Mainly qualitative	Mixed
Findings	Findings are true	Finding are literally created	Findings are probably true

Source: Adapted from (Creswell, 2003; Denzin & Lincoln, 1998; Neuman, 2006; Perry, Riege, & Brown, 1998).

3.2.5 The critical realism approach

Drawing on the main characteristics of abductive research logic which match this research's objectives, the most appropriate approach that may fit within this research is critical realism. Critical realism has become an important perspective in modern philosophy and social science (Archer et al., 1998), Critical realism was developed as an alternative to positivism as well as an alternative to postmodernism and constructivism (interpretivism) (Carlsson, 2003). Before discussing this approach in detail, the research commences with a summary of the main philosophical features of this approach as shown in table 3-4.

Table 3-4: Critical realism approach

Philosophy	***Critical realism approach***
Ontology	Objective reality can be attained only imperfectly and probabilistically.
Epistemology	Objectivism is modified so that it is possible to approximate reality.
Methodology	Focusing on falsification of hypotheses may use experiments, surveys, and case studies.

Source: Adapted from, (Denzin & Lincoln, 1998, pp. 202-09).

Bhaskar (1978) argues that reality and the "representation of reality" operate in different domains. In other words, the existing reality is totally independent of our representation of it (Neuman, 2006, p.96). Critical realists' believe that observation is value-laden, as reality is an outcome of social construction in which social actors are involved in constituting this knowledge. Hence, critical realism advocates that reality and value-laden observation of reality operate in different dimensions. Hence, critical realism considers the nature of the world under study as an integral component of the research process (Dobson, 2002).

Rationale for critical realist approach in this research

There are a number of considerations that have influenced the decision to choose a critical realist position in this study. Firstly, this research adopts an extended resource-based view as a relatively new theory, which requires more empirical work to verify its assumptions within operations and supply chain management context. Secondly, although supply chain visibility is not a new area of research, it is still immature and more investigation is needed to establish and validate its academic contribution. Thirdly, the incremental trend towards new supply chain and ICT applications accompanied by the emergence of advanced tracking and tracing technology, entail revisiting and informing existing supply chain knowledge to develop a better understanding of its enduring structure. *Fourthly*, this study treats asset visibility as a corner stone of product supply chain management. Asset visibility is the fundamental outcome of asset management systems which have become increasingly significant with the evolution of innovative data capture technology and specifically RFID. This new system as a driver for enhanced asset visibility needs deep investigation to explore its technological and managerial capabilities.

Drawing on these considerations, the novelty of the research phenomenon entails unknown information that needs to be uncovered. This may lead to the development of new knowledge and may be generalisable under certain conditions. This new knowledge would be influenced by empirical observations that consider participants values (value-laden observation), then testing hypotheses through empirical application. Smith (2005) stated that critical realist approach offers a viable and appropriate philosophical underpinning for IT and ICT research (whether conducted directly or indirectly) through providing a qualified naturalist approach for social science. Hence, critical realism is the most appropriate approach for this research.

3.3 Practical considerations of social research

Drawing on figure 3-1 and in corresponding to the research philosophical stance, practical considerations are concerned with choosing the appropriate research strategy that in turn influences other methodological decisions related to time horizon, data collection strategy and its techniques, sampling, unit of analysis, and data quality issues. The following sections discuss the practical research considerations in detail.

3.3.1 Research strategy

Research strategies operate at a more applied level of methodologies to provide a specific direction for the procedures of research design (Creswell, 2003). Saunders et al., (2007) argue that the main factors of choosing research strategy are the ability to answer research questions; meeting the research objectives; the extent of existing knowledge[4]; the availability of research resources (e.g. time, money); and the research's underpinning philosophy.

Research strategies vary according to research purpose. The main purposes of research can be exploratory, descriptive, explanatory or predictive (Brewer, 2007; Yin, 2003). These strategies are intertwined with the logic of the research process, i.e. deductive, inductive, and abductive. These strategies are not mutually exclusive (Saunders et al., 2007). This research is not a descriptive or a predictive study; hence, the main focus here is on exploratory and explanatory research strategies. The research draws, in turn, on both strategies.

Exploratory study is employed when little or no information is available about certain phenomenon (Sekaran, 2003). It is usually conducted during the initial stage of the research process. The primary procedure of exploratory study is to refine the problem into a researchable one. The exploratory researcher must be creative, open minded, and flexible. The main purposes of exploratory research are to narrow the scope of the research topic; to transform the discovered problems into defined ones; to obtain a better understanding of the research topic and its limitations and to incorporate specific research objectives (Zikmund, 2000).

Exploratory research is conducted through certain research techniques that include secondary data analysis, pilot studies, case studies, and experience surveys (Zikmund, 2000). It basically applies qualitative methods for collecting data, as qualitative research tends to be more open to using a range of evidence and discovering new issues (Neuman, 2006).

Rationale for exploratory strategy in this research

This research seeks to develop a better understanding of the factors affecting supply chain visibility with a special focus on product supply chains. It also aims to explore the limitations of attaining this visibility. Hence, it is apparent that exploratory study is the most appropriate strategy for data collection in order to meet the preliminary objectives of the research. The outcome of this research process allows the researcher to determine

[4] Existing knowledge depends on the stage to which knowledge about the research topic has advanced.

the types of data to be collected and the method in which the research should be conducted.

Explanatory study may also be called causal research (Zikmund, 2000), analytical research (Brewer, 2007), or hypotheses testing study (Sekaran, 2003). It emphasises the study of a problem in order to explain the cause-and-effect relationships between variables (Saunders et al., 2007). Pawson and Tilley (1997, p.71) presented the logic of realist explanation as follows:

"The basic task of social inquiry is to explain interesting, puzzling, socially significant regularities (R). Explanation takes the form of positing some underlying mechanism (M) which generates the regularity and thus consists of propositions about how the interplay between structure and agency constituted the regularity. Within realist investigation there is also investigation of how the workings of such mechanisms are contingent and conditional, and thus only fired in particular, historical or institutional contexts (C)". Pawson and Tilley summarize this logic in the following equation: Context(C) + Mechanism (M) = Outcome (O). The outcome might confirm or falsify the generated hypotheses or propositions. Explanatory research is conducted through experiments or surveys.

Rationale for explanatory strategy in this research

The primary objective of this research is to develop an integrated model for supply chain visibility to be a source of sustainable competitive advantage. This entails testing a number of causal relationships between various constructs translated into the form of hypotheses, further details are provided in the quantitative analysis chapter, p.239. Thus, an explanatory study is seen as appropriate to attain the main research objective.

3.3.2 Time horizon

Since research design is related to the use of time, different research questions or issues can incorporate time in different settings. Drawing on the time dimension, research may be cross sectional or longitudinal (Neuman, 2006). Cross sectional research covers a single point of time (known as a snapshot approach), whilst longitudinal research covers multiple points of time. The main advantage of cross sectional research is financial due to the fact that it is considered the simplest and cheapest option. One limitation however, is its inability to be used to depict the development of certain social process or social change. Cross sectional research may be used in all types of research (exploratory, descriptive, explanatory, and predictive). Alternatively, longitudinal research studies characteristics of individuals or groups or any unit of analysis at more than one single point of time. Though it is a powerful method, longitudinal research is more complicated and costly. It can be used in both descriptive and explanatory research.

Rationale for cross-sectional approach in this research

This research is interested only in a snapshot of current supply chain practices that might influence supply chain visibility mainly those associated with asset visibility and then testing the effect of such visibility on SCA. Furthermore, the research does not intend to investigate any concept developed by the researcher to examine its influence across different points of time. In addition, practically, this research is constrained by a time frame that does not allow the use of longitudinal study. Hence, cross-sectional approach is the most appropriate option for this research.

3.3.3 Mixed methods approach

Applying both exploratory and explanatory strategies implies adopting a mixed methods approach that has different characteristics from a mono-method (qualitative or quantitative), see table 3-5. The mixed methods approach allows contrasting methods that can be helpful in conducting deep analysis of data as one method informs the other.

Tashakkori and Teddile (2003) and Denscombe (2007) state that the main advantages of mixed-methods research are *Triangulation*[5] (validating data and results by merging a number of data sources, methods, or observers), *practicality*, (problem-driven approach to research rather than theory driven), *Creativity* (finding out gaps for further work), and *Expansion* (enlarging the scope of the study).

[5] Triangulation involves the practice of viewing things from more than one perspective, i.e. the use of different methods, different sources of data, or even several researchers within the study.

Table 3-5: Qualitative, quantitative, and mixed methods approaches

	Qualitative	***Quantitative***	***Mixed-methods***
Research approach	Interpretivism	Positivism	Critical realism
Objective	To construct social reality, cultural meaning	To measure objective facts	To develop a rationale for integrating both goals.
Focus	Focus on interactive processes, events	Focus on variables	Focus on both
Tool	Authenticity	Reliability	Rational integration of both
Data collection methods	Narrative Phenomenology Ethnography Grounded theory Case studies	Experiments and surveys	Sequential, simultaneous, or transformative exploratory/explanatory design
Questions	Open-ended questions	Closed-ended questions	Mixed
Data type	Text and/or image data	Numeric data	Mixed
Values	Value-laden	Value free	Rational of Value laden observation
Data analysis	Thematic analysis	Statistical analysis	Thematic and statistical analysis

Source: Adapted from (Creswell, 2003; Neuman, 2006).

Conversely, the main disadvantages of using the mixed methods approach relate to the possibility of increasing the time and cost of the research project.

Rationale for mixed methods in this research

Since this research adopts a critical realist approach, the most appropriate research strategy for this approach is mixed methods. Although using mixed methods requires more time, effort, and cost, this enriches the research data and deepens the analysis leading to richer, more reliable, valid findings.

3.3.4 Data collection strategy within mixed methods

Many authors have illustrated the criteria of choosing a mixed methods strategy such as Tashakkori and Teddlie (2003) and Morgan (1998). Table 3-6 illustrates four factors for selecting mixed methods strategy of inquiry.

Table 3-6: Data collection within mixed methods

Data collection	***Priority***	***Integration***	***Theoretical perspective***
Simultaneous	Equal	At data collection and at data analysis	Explicit
Sequential qualitative first	Qualitative	At data interpretation	Implicit
Sequential quantitative first	Quantitative	With some combination	

Source: Adapted from Creswell (2003, p.211).

Drawing on the previous table, six main strategies for the data collection process in social research are presented:

Sequential explanatory design entails collecting and analysing quantitative data then collecting and analysing qualitative data followed by interpreting the entire data. The purpose of this strategy is to use qualitative results to support the interpretation and explanation of findings of the primary quantitative study.

Sequential exploratory design requires collecting and analysing qualitative data, collecting and analysing quantitative data, then interpreting the entire data. The purpose of this strategy is to use quantitative data and results to help in the interpretation of qualitative findings.

Sequential transformative design has two distinct data collection phases; one follows the other. The main purpose is to employ the methods that will best serve the theoretical perspective of the researcher.

Simultaneous triangulation strategy is the most familiar strategy that is applied when the researcher uses two different methods to confirm and cross validate findings within a single study (Greene, Caracelli, & Graham, 1989; Morgan, 1998)

Simultaneous nested strategy: it is recognised by its use of one data collection phase in which both qualitative and quantitative data are collected simultaneously; one predominant method guides the research.

Simultaneous transformative strategy is guided by adopting a specific theoretical perspective. It is reflected in the purpose of the study or the research questions and is the driving force beyond all methodologies. The design of simultaneous transformative strategy may take a feature of either triangulation or a nested approach.

Rationale for sequential exploratory strategy in this research

Drawing on the various types of inquiry or data collection process, the research adopts a *sequential exploratory strategy*. The research commences with exploring the key capabilities or factors associated with asset visibility as an integral part of overall supply chain visibility. The research adopts ERBV which is relatively new and also requires more academic work to be tested, verified and refined within supply chain context. Asset visibility provides a typical example through which ERBV assumptions can be proved. Since sequential exploratory design is appropriate when testing elements of an emergent theory or construct informed by a qualitative study that can be generalised based on a quantitative study (Morgan, 1998), it is an appropriate strategy in this research. As stated earlier the principal objective of this research is to develop an integrated model for supply chain visibility to be source of SCA and to empirically test this model, Creswell (2003) states that a sequential exploratory strategy is often discussed as a model used when a research develops and tests an instrument.

3.3.5 Sampling

Sampling is the process of selecting the right individuals, objects, or events for study (Sekaran, 2003). A sample is defined as a set of subjects from which data is collected (Thietart, Royer, & Zarlowski, 2001). The subject is a single unit of a sample and the element is the single unit of the population (Sekaran, 2003). Sampling techniques present a number of methods that help the researcher to reduce the amount of data s/he needs to collect by considering only data from subgroup rather than all possible cases (Saunders et al., 2007).

There are two key types of sampling techniques used in social research: probability sampling (representative sampling) and non-probability sampling (judgemental sampling) (Denscombe, 2007; Sekaran, 2003). Probability sampling is widely used in quantitative research and means that people or events in the population that are chosen as a sample have equal opportunity or probability to be selected as a sample by the researcher (i.e. it should be representative for the population). Non-probability sampling is more related to qualitative research, there is no predetermined chance or probability that people or events can be chosen as a sample (i.e. it is not representative for the whole population). Thus, the main differentiation factor between both types is the ability to generalise findings. Findings may be generalised with probability sampling but may not with non-probability sampling.

In qualitative research the primary purpose of sampling is to collect specific cases, events, or actions that can clarify and deepen an understanding of a phenomenon (Neuman, 2006), yet in quantitative research the primary objective of sampling is to acquire a representative sample that can explain, describe and/or predict certain phenomenon.

Rationale for sampling in this research

Drawing on the two stages of the research, the objective of the first stage is to investigate certain cases or entities that are affiliated with product-based supply chain to explore the capabilities associated with asset visibility that might influence overall supply chain visibility. In this stage, the main concern is to develop better understanding of the research problem rather than generalising findings. Hence, non-probability sampling is adequate for the pilot study stage. The main objective of the second stage of the research is to refine these capabilities or factors to obtain the most influential ones and then test a model for supply chain visibility through which SCA might be attained. A representative sample in this stage is required for the purpose of validating the pilot study findings. Hence, probability sampling is more appropriate for the second stage of research. A detailed discussion of the sampling techniques used in this research is provided in the pilot study section (3.4) and the survey sampling section (3.5.1).

3.3.6 Data collection techniques

Data collection is an integral part of the research design. In the light of the chosen data collection strategy of this research (sequential exploratory design), data collection is conducted through two stages; the pilot study stage, which in turn informs the survey as the core phase in this research. In considering data collection techniques, techniques of data collection vary according to the type of data; qualitative or quantitative i.e. text, image, voice, or numeric. Techniques that are used in qualitative research are observations, interviews, focus group, panels, documents and/or audiovisual materials (Flick, 2002). On the other hand, quantitative research uses two main techniques, these are structured interviews and/or questionnaires (Denscombe, 2007; Sekaran, 2003). Data collection technique choice relies on available facilities, the degree of precision required, the expertise of the researcher, the available time of the study and allocated resources for collecting data, mainly time and money (Sekaran, 2003).

Rationale for data collection techniques in this research

For the preliminary stage of the research, the employed technique of in-depth site-based interviews was seen as an appropriate option for exploring the research questions (Hill, Nicholson, & Westbrook, 1999; Stuart, McCutcheon, Handfield, McLachlin, & Samson, 2002; Zikmund, 2000). For the purpose of triangulation, observations and documents are used within the pilot stage. In considering the second phase, a self-administered questionnaire is employed.

A detailed discussion of the employed data collection techniques is introduced in sections 3.4.2 and 3.5.3 representing, respectively data collection techniques for the pilot study and data collection techniques for the survey.

3.3.7 Unit of analysis

The unit of analysis refers to the aggregation level of collected data during the data analysis stage (Sekaran, 2003). It is determined by the research questions (Yin, 2003). The unit of analysis in operation management studies may be individuals, dyads, groups, plants, divisions, companies, projects, systems, etc (Flynn, Sakakibara, Schroeder, Bates, & Flynn, 1990). The individuals surveyed could be representatives of themselves, their project, their expertise, or their organisation (Malhotra & Grover, 1998). Because research questions may imply issues or need to be investigated within more than one stage of data collection, the research may imply more than one level of analysis.

Rationale for unit of analysis in this research

The basic unit of analysis in this research is a focal firm in a product-based supply chain that ships its final products, intermediate products or production supplies across its downstream supply chain. The focal firm might be manufacturing or non-manufacturing firms such as retail and healthcare firms. Here no differentiation needs to be made between manufacturing and service companies as the research focuses on supply chain operations rather than the final product itself.

3.3.8 Data quality

Both qualitative and quantitative social researchers want to achieve reliability and validity in their measures as central issues in all measurements that help to establish the truthfulness and credibility of findings (Neuman, 2006). Reliability and validity are usually complementary concepts. While *reliability* means dependability or consistency (i.e. the same thing is repeated under the same conditions), *validity* refers to truthfulness (i.e. the ideas (social reality) being measured by the research matches the construct the researcher uses to understand it) (Neuman, 2006). Beyond agreement on the basic ideas at a general level, reliability and validity have different types and techniques in both qualitative and quantitative research.

Since this research includes two stages of qualitative and quantitative data collection, reliability and validity of both measurements are discussed in detail later in this chapter. The following sections draw on details of the pilot study and survey phases, respectively and the associated methodological decisions.

3.4 Pilot study

The exploratory stage was conducted through a pilot study which is any small scale exploratory research that can guide a larger study through providing background information (Denscombe, 2007). It uses sampling but does not apply rigorous standards (Zikmund, 2000). Because the main objective of exploratory research is to gain deeper understanding and to unearth the ambiguity of new phenomena, the researcher can adopt considerable creativity and flexibility. Zikmund (2000) argues that a pilot study uses data collection methods that are informal and its findings may lack accuracy. The researcher claims that the accuracy issue can be solved through use of other strategies in the same research, whilst acknowledging that a pilot study should not be used as a single data collection strategy.

Rationale for pilot study in this research

A pilot study explored the research objective related to gaining a deeper understanding of the capabilities affecting visibility, especially those related to asset visibility (a relatively new phenomenon associated with innovative practices). In this early stage it is common to collect data with several exploratory techniques, reflecting the creativity, flexibility and malleable standards discussed in relation to pilot studies.

For the pilot study stage, a chief case study has been selected using a purposive sampling technique (Saunders et al., 2007). The researcher primarily chose one in-depth site-based case representing two types of product-based supply chains using innovative RTAM system specifically RFID. Thus, three core sub-cases were conducted on two kinds of product-based supply chain.

3.4.1 Pilot unit of analysis and key informants

The pilot study stage included both the site-based case study and additional field-expert interviews. The research concentrates on the focal firm in a downstream supply chain represented through a supply chain and logistics department which is responsible for an asset management system. Informants from the case company are viewed as primary informants. In considering the business case, the informants are affiliated with the supply chain department at different organisational levels ranging from top management to the operational level. This facilitates the opportunity to capture more information about the RTAM system capabilities on different levels. For the sake of exploring the technological capabilities of the RTAM system, a representative of the RFID solution provider's company who provides the IT service to the case company was also interviewed. For the purpose of supporting and validating the case findings, field experts in the area of SCM and tracking technology were also interviewed as secondary informants.

3.4.2 Data collection techniques for a pilot study

Zikmund (2000) argues that using a *focus group* in a pilot study is appropriate in order to overcome the informality and malleable standards associated with pilots. A focus group is formed of 8-10 participants and it is conducted for something like two hours. Such a technique would not have allowed enough time, sufficient detailed information, or the empirical observation deemed to be required in this research. Hence, it is not suitable to be employed in this research. The *projective technique* is another data collection method for a pilot study through which the main purpose is to discover individuals' attitudes, motivations, defensive reactions, and characteristic ways of responding, it may use disguised questions (Zikmund, 2000). However, this technique is not appropriate for this research which is conducted with "real" managerial and technological practices of business not personal attitudes or motivations. An *instrumental case study* used to understand specific phenomenon rather than the case itself corresponds well to business research (Healy & Perry, 2000). Hence, an instrumental site-based case study using mainly in-depth semi-structured interviews as a data collection technique is relatively unstructured and has been extensively used in the primary stages of the research process (Hill et al., 1999; Voss, Tsikriktsis, & Frohlich, 2002; Zikmund, 2000).

In-depth site-based interviews can be managed as a dialogue between more than one interviewee and more than one interviewer that control the limitations of these interviews and enrich their outcome. Zikmund (2000) highlights the important role of an interviewer in managing in-depth interviews to stimulate participants to provide all the available information related to the topic being discussed without any reflection on the direction of the conversation. To reduce subjectivity, the researcher has used a simple triangulation technique based on using three interviewers (two colleagues and the researcher) to guarantee that at least two interviewers attended each interview. The analysis and interpretation made by the researcher have been revised by the other two interviewers who are experts in the field. To enrich and validate the pilot study findings, triangulation of data sources has been used through three sources of secondary data including observation, documents and field-expert interviews.

The following two sections draw on secondary data collection techniques used within the pilot stage related to site-based case research which includes observation and documents.

3.4.3 Secondary data collection

For the purpose of avoiding any source of bias or limitation associated with the use of an individual case study, triangulations of data collection techniques are used. This includes the use of field-expert interviews, observation, and documents (Neuman, 2006). Field-expert interviews were conducted relying on the semi-structured interviews technique as discussed in the previous section. Two techniques directly associated with a sit-based case are observation and documents that were implemented to collect secondary data within the pilot study stage. The research draws now on each technique in turn.

Observation

According to Sekaran (2003) There are two main types of observation; *nonparticipant-observer* and *participant-observer.* In the first type the researcher collects data from the organisation without being involved in the organisational system. Non-participant observers usually enter the research setting with knowledge of what they want to observe and why (Briggs & Coleman, 2007). In the second type the researcher becomes an integral part of the organisation or of the natural setting to observe the dynamics of the system. Here the observers often have no pre-determined view about what data will be collected and how it will proceed (Briggs & Coleman, 2007). Within these two types of observation Sekaran (2003) states that there is an interior classification: *structured observation* and *unstructured observation*. Structured observation refers to a predetermined set of categories of the activities of the research phenomenon that are intended to be investigated. On the contrary, unstructured observation has no definite plan for which data is required to be collected. This type of observation is used at the beginning of the study when the researcher tries to explore the research phenomenon and depict its main aspects. In this case the researcher needs to record practically everything that s/he observes.

Rationale for observation technique in this research

Drawing on the main features of the two classifications of observation technique, the researcher intends to adopt unstructured *non-participant site-based observation*. This type of observation is only used within the pilot study phase as a means of exploring the research phenomenon and to understand how the system works. Hence, the researcher involvement in the organisational system is not required. The incorporation between the outcomes of both in-depth interviews and observation based on three site-visits enriches the research findings.

Documents

Although, social research can conduct empirical research based on the documents technique, it always intertwines them with primary data collection methods that make it more powerful. Saunders, et al. (2007) divided document sources into two groups. The first group is *written materials* such as organisation databases e.g. personnel or production, organisation communications such as emails, letters, memos, organisations websites, reports and minutes of committees, journals, newspapers, diaries, interview transcripts, public records. The second group is *non-written materials* such as voice and video recordings, pictures, drawings, films, television and radio programs. Both written and non-written documents can be quantitatively or qualitatively analysed, they can be used to help triangulate findings.

Rationale for documents technique in this research

For triangulation purposes, written documents and non-written documents as secondary data have been used within the pilot study stage along with in-depth interviews and site-based observations. These written documents include technical and operational information concerned with the company's tracking system using RFID. Photographs taken by the researcher during the site visits as non-written documents have added a visual dimension that supports the description of some technical aspects; see chapter 4, p.179.

3.4.4 Pilot study protocol

Three site-visits were planned considering different locations and different settings. Three visits were arranged between February and October 2009. The site-visits allow simultaneous participation of more than one interviewee in each interview. As such, the same question was answered by multiple participants in an interactive way, see appendix A, p.391. The trade-off between the efficiency and richness of data collected was considered through trying to keep the track of the group discussion during the interview. Positively, group interview mitigates the risk of single respondent's bias and subjectivity. In addition, it helped in validating the research findings. On the other hand, using more than one interviewer controlled the discussion and allowed effective manipulation of key ideas during the interviews. It also enhanced the internal validity of the findings.

The site-visits were supported by live site-pictures as a type of document to add a visual dimension to case findings. In addition, text documents provided by case informants were employed limitedly for the purpose of understanding why and how the transition from the previous RTAM system to the current one was made and the consequences of this. This deepened the researcher's assimilation of the research phenomenon.

Prior to conducting the actual interviews, permissions were sought to use audio recording and to take photographs at the site. With regard to ethical research considerations, confidentiality and anonymity of informants and company were guaranteed, so for example, neither interviewees, nor other company's staff or the company's logo/name were photographed.

To add knowledge about outsourced logistics, field-expert interviews were conducted by telephone. The interview's questions were adjusted to achieve the purpose of the interviews, see appendix B, p.292. Invitation emails were sent to the interviewees (experts) that explained the purpose of the study and invited them to take part in the interviews. Confidentiality and anonymity concerns were firmly assured and a statement of thanks was added. Data quality of these measurement instruments are checked through the criteria of reliability and validity applied in qualitative research. The fprocedures taken to ensure the data quality of the pilot study findings are presented within chapter four, p.189.

3.5 Survey

Researchers distinguish between three types of surveys; exploratory, explanatory (confirmatory or theory testing) and descriptive (Malhotra & Grover, 1998). However, survey as a data collection strategy for explanatory study has emerged recently as one of the most popular approaches to social research (Denscombe, 2007). Surveys as a method to test theoretical assumptions among variables have been employed extensively in production and operations management (Malhotra & Grover, 1998). It requires asking people, known as respondents, for information using either verbal or written questions. Survey research is built on the logic of deductive inquiry (which is required in the second stage of the research) through its emphasis on reliability in data collection and the statistical control of variables. Neuman, (2006) summarises the logic of survey as follows (1) to sample many respondents who answer the same questions; (2) to measure many variables; (3) to test hypothesis/hypotheses; and (4) to infer temporal order from questions about past behaviour, characteristics, or experiences.

Gill and Johnson (2002) intimate that survey strategy occupies an intermediate position between ethnography and experimental research. Gill and Johnson (2002) justify survey's intermediate position as the survey takes different forms according to the researcher's decision about the type of investigation i.e. descriptive, causal, or correlational. Indeed, most surveys are descriptive, yet they are also designed to provide explanation or to explore ideas (Zikmund, 2000). Sekaran (2003) suggests that causal studies seek causes constituting the research's problem, while correlational studies search for significant factors associated with a research problem.

Rationale for survey in this research

The key purpose of conducting a survey as a primary phase in this research is to refine the factors influencing asset visibility and then to test to what extent these factors predict supply chain visibility. The research seeks to examine any mediating effect of visibility and of a firm's performance, on SCA. The survey strategy provides a quick, inexpensive, efficient and precise tool for assessing information about the population (Zikmund, 2000). Survey strategy confirms generalisability i.e. external validity of results due to a simultaneous snapshot investigation of numerous firms.

The main issues associated with surveys are the sampling decision, data collection procedures and data quality; these issues are discussed sequentially in the following sections.

3.5.1 Survey population and sampling

Probability sampling is associated with survey research in which the researcher needs to make inferences from the sample about a population to answer the research questions (Saunders et al., 2007). The decisions regarding sampling is made by identifying population; sampling frame; and sample size; choosing the most suitable sampling technique; and checking that the sample is representative of the population. The following sections shed the light on these stages and the decision on each of them is made.

Population

The survey was conducted in association with the Charter Institute of Purchasing and Supply (CIPS) based in UK who allowed the use of their database. In this study, the CIPS database is considered the population. CIPS is formed of 65,000 members of organisations, academics, and individuals. The use of CIPS database allows the selection of a cross-sectoral sample as a key advantage (Carey, 2008). Different public and private economic sectors are represented in CIPS including manufacturing, service and non-profit. The high number of members affiliated with various sectors and the number of research papers published in well-regarded academic journals that used the

CIPS database are indicators of the accurate representation of the population. This also reduced the possibility of sampling frame error.

Rationale for population decision in this research

The main interest of this research is to investigate the influence of asset visibility capabilities on supply chain visibility. The study considers the type of tracking system e.g. manual versus automated as an influential factor for asset visibility. To date there is almost no available index or database that provides information about firms' tracking systems. It is also time-consuming and costly to prepare this kind of list (Zikmund, 2000). As such, the CIPS database is seen as an appropriate source of data for this research.

Sampling frame

A probability sample depends on the availability and accessibility of a sampling frame. The sampling frame is also called the working population which is a list of all individual members of a certain population that provides a theoretical access to each and every member of that population (Briggs & Coleman, 2007). It is generally not feasible to compile a list that does not exclude some members of the population that is caused by a sampling frame error (Zikmund, 2000). A sampling frame error may also happen when the entire population is not accurately represented in the sample frame. While a sampling error is random, sampling bias is non-random and systematic that in turn negatively affects the generalisability of the research findings (Tashakkori & Teddlie, 2003). Therefore, the researcher should ensure that the sample is representative to its population which then supports and validates the research findings.

Rationale for sampling frame decision in this research

The sampling frame of this research is represented through 800 firms that were randomly contacted by CIPS administrators. The sampling frame combines medium-to-large manufacturing and service firms in UK. Although, this research is interested only in product-based supply chain it considers both manufacturing and service firms. As such, the industries included in this study are classified into four categories: 1) Aerospace, Defence, and Automotive; 2) Healthcare, IT, Telecommunication, Utilities, Mining, and Energy; 3) Logistics, Retail, FMCG (Fast Moving Customer Goods); and 4) Other manufacturing firms including electronic, pharmaceutical, chemical, paper products and general manufacturing. Including the variety of firms to constitute the sampling frame enriches the extent of the external validity of the research findings. Any other firm beyond the aforementioned categories has been excluded from the sample.

Sample size

Because a probability sample is based on statistical probability, the larger the sample size the less the expected errors, so that more valid and reliable findings are expected. However, this cannot guarantee precision (Bryman & Bell, 2007). There are many factors that affect the decision on sample size. Sekaran (2003) and Saunders et al. (2007) illustrate these factors as follows: 1) The confidence required in the data to guarantee the level of certainty that the characteristics of data collected from a sample represent the characteristics of the population, a larger sample size is required for greater confidence; 2) The accepted percentage of error that implies the required level of accuracy and precision when making the estimation from the sample to the population; 3) Types of data analysis the researcher intends to implement; 4) The size and variability of a population from which the sample is taken; and 5) The number of different variables examined simultaneously in data analysis.

Indeed, the decision about a sample size in many cases is made based on practical considerations subject to judgment rather than statistical ones based on calculations. These practical considerations include budget, time and other resources' limitations (Bryman, 2008; Saunders et al., 2007). Thus, the sample size decision is a compromise between the targets of conducting a survey and the resources available to achieve these targets (Haynes, 1982).

Rationale for sample size decision for the survey

In this research, the sample size is 129. Practically, the expected response rate in survey research especially online ones conducted in operations and supply chain management is low; approximately 10% (Klassen & Jacobs, 2001). This means that for the sample frame of 800, 80 responses would be considered acceptable. This response rate is appropriate for the proposed statistical techniques in this research, mainly regression analysis. Discussion about the appropriateness of sample size to the employed statistical techniques has been made in the quantitative analysis chapter, p.239.

Sampling techniques

Probability sampling techniques are based on random selection procedures which eliminate bias shaping a non-probability sample (Zikmund, 2000). These procedures are illustrated in table 3-7. This randomness allows equal opportunity for all of a population's elements to be selected as a sample's subject. There are two main techniques of probability sample: *simple random sample*, *and complex random sample* that includes systematic, cluster and stratified samples. Table 3-7 shows the main characteristics, advantages, and disadvantages of each sample technique.

Table 3-7: Probability sample techniques

Sample type	***Procedures***	***Characteristics***	***Evaluation***
Simple random sample: - All elements in the population are considered and each of them has the same chance of being selected as a subject.	- Creating a sampling frame for all the population's elements, and then selecting subjects using a purely random process such as random-number table[6] or computer program.	- Accurate and easy accessible sampling frame required; - Sample size is better with over a few hundred ; - Wide coverage of many geographical areas, unless face to face contact is required.	***Advantage:*** - Generalisability of findings is high. ***Downside:*** - Lack of efficiency compared to stratified sample; - High cost with large sample size; - Not frequently used in practice.
***Systematic random sample*:** - A systematic selection process selects the first element randomly from the sampling frame and then every n^{th} number on the list is selected.	- Creating a sampling frame, - Calculating sampling intervals[7], - Choosing a random starting point and then drawing subject at every interval.	- Require accurate and easy accessible sampling frame with no periodic patterns; - Suitable for all sample sizes; - Wide coverage of many geographical areas, unless face to face contact is required.	***Advantage:*** - Easy to use with availability of sample frame; - Relatively moderate cost; Moderately used. ***Downside:*** - Possibility of systematic biases
***Stratified sample*:** - A probability sampling procedure in which sub-samples are drawn from samples within different sub-groups or strata that have some equal characteristics.	- Creating a sampling frame for each of several categories of elements, drawing a random sample from each category, and then combining all	- Clear logic beyond adopting stratified sample; - Required accurate, easily accessible sampling frame that can be divided in relevant strata; - Suitable for all	***Advantage:*** - Most efficient compared to all probability samples; - Better representation of relative population allowing more accurate findings; - Low cost if the

[6] Random-number table is a list of numbers that has no pattern and it is used to create random process for selecting sample's subjects.
[7] Sampling interval is the number of population elements between the subjects selected for the sample.

	samples' categories.	sample sizes; - Concentrated if face-to-face contact required, otherwise it has wide geographical area coverage.	sampling frames are available; - Moderately used; - Allowing deeper view in data analysis. ***Downside:*** - Time consuming; - Required sampling frame for each stratum.
Cluster sample: - An economically efficient sampling technique in which the population is divided into discrete groups or clusters prior to sampling that can be based on any naturally occurring grouping, e.g. geographical areas and manufacturing firms.	- Creating a sampling frame for larger cluster units, - drawing a random sample of the cluster units, - creating a sampling frame for cases within each selected cluster	- Geographically based clusters; - Required accurate, easily accessible sampling frame that relates to relevant clusters; - Sample size is as large as practicable;	***Advantage:*** - Low cost of data collection if sampling frames are available; - Frequently used. ***Downside:*** - The least efficient and reliable sampling technique.

Source: Adapted from (Saunders et al., 2007; Sekaran, 2003; Zikmund, 2000)

Drawing on table 3-7 and for practicality reasons related to limited access to the sampling frame, the most appropriate sampling technique for this research is the simple random sample.

3.5.2 Survey unit of analysis and key informants

In this research, the unit of analysis is the focal firms, specifically focused on their downstream supply chain activities. The key informants who represent their firms are middle-level supply chain managers or equivalent positions. This managerial level is suitable for providing valid responses to the research questions and associated hypotheses. To put it another way, these managers should have sufficient knowledge and a comprehensive view of their firms' tracking system, ICT and supply chain applications, inter/intra-firm relationships including relationship with 3PL, visibility and performance level and competitive situation.

In order to eliminate *informant bias* and to evaluate their competency for the survey, specific questions were related to the number of years the informant had been with the firm, job-title and the period the informant has held their position. Answers from participants who are knowledgeable are trusted and minimise random or bias error (Forza, 2002).

Social desirability bias which happens when informants give a socially acceptable response or show desirable organisationally practices instead of an honest answer was tackled through confirming anonymity of informants and confidentiality of responses (Huber & Power, 1985; Neuman, 2006). Other factors might participate in mitigating the effect of social desirability bias. First, the survey questions were not about sensitive information or personal behaviour. Second, an on-line survey conducted through a professional database allows a high level of anonymity (Neuman, 2006), therefore, the respondent is aware that his/her identity and affiliation are totally hidden. Finally, most of the survey's questions are measured on a seven-point likert scale rather than dichotomous questions based on two possible responses.

3.5.3 Data collection techniques for survey research

Questionnaires are the main data collection technique used within the survey strategy in business and management research (Saunders et al., 2007, p.354). Flynn et al. (1990) indicate that survey designs with questionnaires are the most commonly used methodology in empirical production and operations management research. According to Saunders, Lewis, and Thornhill (2007), a questionnaire is a general term that implies all techniques of data collection in which each person is asked to answer the same set of questions in a predetermined order (De Vaus, 2002). A questionnaire can be classified into two main groups: the *structured interview* including, face to face interview, and telephone interview, while a *self administered survey* including internet survey and mail survey where the researcher is not present as it is completed. The main focus in the following section is on a self administered survey as the employed technique in this research.

Self administered survey

Bryman and Bell (2007) refer to the main advantages and limitations of a self administered survey. Table 3-8 summarises the features of this type of survey.

Table 3-8: Evaluation of self administered survey

Advantages	*Limitations*
• Low number of open questions; • Shorter in length; • Easy to follow and answer; • No interviewer variability; • More convenient for respondent; • Cheaper to administer; • Faster to administer; • Absence of interviewer effects; • Wide geographic areas can be reached.	• Respondent cannot be prompted; • No possibility for clarifying answers; • No possibility for more questions; • No possibility for observation; • Risk of missing data; • Not sure who answers; • Lower response rate.

Source: Adapted from (Bryman & Bell, 2007; Sekaran, 2003).

A self administered survey is considered a challenge for the business researcher because it relies heavily on the accuracy and efficiency of the written word rather than the interviewer (Zikmund, 2000); table 3-9 compares the two main types of these surveys.

Table 3-9: Techniques of self-administered survey

Item	*Mail survey*	*Online survey*
Main features	Anonymity is high	Computer literacy is a must, allows flexible design
Resources required	Data entry, outward and return postage, photocopying, clerical support.	Data entry in the form of an e-mail, or designing a web page using online expert systems or software providers.
Characteristics of respondents	Literate people who can be contacted by mail; selected by name, household, organisation.	Computer-literate, people who can be contacted by email, internet, intranet.
Confidence that response is from the right person	Low unless collecting answers in person	High in case of electronic mail survey
Possibility of distortion responses	Low	May happen if consulting with others
Sample size	Large, tends to be locally dispersed due to associated cost.	Very large and may be locally or internationally dispersed
Response rate	Variable yet 30% is reasonable	Variable, 11% or lower, 30% if using intranet
Types of questions	Closed questions with simple sequencing only	Closed questions, complicated sequencing may be available
Response time	Ranged from days to weeks to months	Ranged from minutes to hours to days to weeks.

Time for complete collection of responses	Depends on sample size; the average is 4-8 weeks from distribution	Varies according to sample size; the average is 2-6 weeks from distribution
Negative features	Response rate is relatively low, no possibility for clarifying questions; following up procedures is time consuming; responses are distorted if consulting with others.	Response rate is quite low; respondent must have access to a facility, should be well designed and in the interest of respondents to be willing to complete it.

Source: Adapted from (Bryman & Bell, 2007; Neuman, 2006; Saunders et al., 2007; Sekaran, 2003).

Rationale for online survey in this research

Drawing on the table 3-9, the advantages of an online self administered survey minimise the risk of losing the respondent's failing to complete due to tiredness or boredom. The approach is also time and cost effective. Disadvantages such as the risk of missing data and a low response rate can be mitigated through certain techniques for increasing response rate (Bryman & Bell, 2007; Saunders et al., 2007), see increasing response rate section (3.5.8, p.89). Other disadvantages relate to the absence of the researcher e.g. no possibility of clarifying answers or asking more questions and can be overcome by using closed questions. Moreover, the design of survey was informed by the findings of the pilot study, which minimised the need for open questions and enhanced the reliability of employed measures and validity of research findings.

3.5.4 Survey pilot testing

In addition to a methodical survey design process, pretesting of the measurement instrument was conducted to highlight any problems before the survey went live and to establish the importance of the study among practitioners and academics (Malhotra & Grover, 1998; Sue & Ritter, 2007). Pretesting of the survey as an integral part of the survey design process gives feedback on the wording and layout issues that ensure the clarity and the ease of completion (Flynn et al., 1990). It also allows testing the content validity of employed measures i.e. the extent to which the items can measure the constructs that they are supposed to measure. The researcher followed the pilot testing procedures proposed by Forza, (2002). These procedures entail checking the survey by three groups of people: academics, field experts, and potential informants. Employing their various levels and types of experiences and knowledge of the operations and supply management area in the pilot process, confirmed the legitimacy and rigour of the survey.

A copy of the survey was emailed to each interviewee at least one week before conducting the interview. The interviewees were asked to have their survey copy during the interviews. Notes were taken during the interviews. Following the funnel pattern, the interviews started with more general questions about the structure, format, wording and layout of the survey, then the questions became narrower and more specific about the content including any suggestions for adding or removing items (Neuman, 2006; Voss et al., 2002). The average length of the interviews was approximately one hour. The number of interviews was determined based on reaching the saturation level of survey improvements i.e. no more changes were expected with more interviews. The survey pilot testing was conducted through three sequential stages with three target groups of respondents as follows.

In the first stage, five academics within Information, Decision and Operations group, School of Management, University of Bath were invited to pilot test the survey through face-to-face semi-structured interviews. This type of interview allows the observation of the interviewee's body language to indicate his/her agreement, disagreement or confusion about something that was considered through taking notes (Dillman, 2000). The selected academics were knowledgeable and experienced in the area of operations and supply management (Dillman, Smyth, & Christian, 2009). The key purpose of conducting these interviews was to examine whether the survey served the research objectives. To that end, a copy of the research conceptual framework along with the research hypotheses was attached to the survey. This gave the interviewees an overview of the research purpose and objectives. The researcher intended to use well-established and reliable scales for all constructs apart from the asset management capability as an immature construct within operations and supply management area. Hence, these interviews examined the face validity of the employed measures specifically those associated with the new measures (Hair, Black, Babin, & Anderson, 2010). Wording and layout issues were examined as well. Based on the interviews with these academics the survey was refined and modified and the second survey draft was developed.

In the second stage, pilot testing was conducted using telephone interviews with two field-experts in the area of supply chain and tracking systems. The key purpose of these interviews was to draw on the interviewee's experience, to obtain feedback mainly on tracking capabilities measures as well as to remove any obvious or impractical questions that may indicate any avoidable ignorance by the researcher in certain areas (Forza, 2002). After attaining the consent for their participation in telephone interviews, the survey was emailed to the interviewees. The email message included an appreciation of their participation as well as explanation of the research purpose and objectives with a special focus on the tracking system. The message also indicated the key areas in which the researcher would like to gain feedback; in addition to tracking system section clarity, understandability, logical order and language of the survey questions. This stage resulted in the deletion of one question and refining of a number of questions. Thus, the survey third draft was created informing the final testing stage.

In the third stage, pilot testing was conducted with a number of target respondents through telephone interviews. The sole purpose of conducting these interviews was to check "how well the conceptualisations of the problem matched the actual experience of the practitioner" (Malhotra & Grover, 1998). Due to an anonymity restriction imposed by the CIPS, the researcher was not able to directly contact any cases. As such, a convenient sample of five cases that are well-representative of the characteristics of the research sample was selected (Bolton, 1993); see sample characteristics section (3.5.11, p.91) Similarly, the respondents were middle-level supply chain managers who have identical characteristics to those of target respondents; see respondent characteristics, p.92. The organisation represented in the exploratory stage was used as one of the phone interviews, representing the communication industry. The other four organisations were affiliated with different industries including pharmaceutical, aerospace and retail. The survey was emailed to respondents requesting them to complete it. The respondents were informed that the survey was in the process of development. They were accordingly asked to assist in improving the quality of the survey through commenting on any problems encountered in answering the survey questions related to ambiguity, instructions, wording, layout and content. The feedback of the participants was considered and changes were made when appropriate, and the final version was developed, see the appendix J, p.455.

3.5.5 Survey wording and layout

Good survey questions as a measurement instrument should provide valid and reliable measures that flow smoothly without confusion leading to a better response rate (Dillman, 2000; Forza, 2002). Two main *wording* issues are considered to eliminate confusion concerned with the use of vocabulary and grammar and the influence of specific words or phrases. Neuman (2006) and Forza (2002) provide the essential factors of question writing that ensure unbiased responses and clarity of survey questions. These factors include avoiding jargon, abbreviations, ambiguity, confusion, vagueness, leading and double-barrelled questions, questions that are beyond informant's capabilities, double negatives, wrong premises and statements or questions more than 20 words. These strictures were followed in creating the survey instrument in this research and maintained within the piloting process, see pilot testing section, (3.5.4 p.83). In addition, reverse worded questions or statements were developed to eliminate the tendency in participants to mechanically choose the options on one side of the scale (Forza, 2002). Rewording the reverse worded items was considered before launching any statistical analysis (Bryman & Cramer, 2005).

Survey layout is crucial in online surveys as there is no interaction between a researcher and a respondent (Sue & Ritter, 2007). For this reason, instructions for completing each of the survey questions were made clear. The use of email survey allows the researcher to automatically control the number of choices that the respondent should select e.g. only one choice or more than one. For the purpose of statistical analysis, most of the survey questions were answered based on making one choice especially for those measuring continuous variables based on Likert scale. Furthermore, flexibility was ensured in answering the survey questions as participants were able to move back to a previous page and revise their responses at any time. No compulsory questions were required i.e. participants did not have to answer any question before moving to any subsequent ones (Sue & Ritter, 2007). Although this may increase the risk of missing data, it ensures valid responses and credibility. Different ways were employed to present the response options including radio buttons (mainly for Likert-type scale), check boxes (mainly related to tracking capabilities questions), and drop-down menus (mainly for background questions).

To avoid respondent fatigue and premature termination of a one-page online survey requiring excessive scrolling (Sue & Ritter, 2007), a multipage format was used i.e. nine pages representing eight sections were developed. A progress bar was used to identify the percentage of the survey completed to allow participants to estimate roughly how much time is needed to finish the whole survey. This may minimise the number of incomplete surveys especially in the case of short to medium surveys. Moreover, an appropriate and consistent format was adopted including font type, text size, colour and background style (Forza, 2002). The consistency of this format was maintained through using one of the templates offered by the web-based survey host. To enhance the familiarity of respondents with online surveys, the selected template of the survey is close to the conventional format of paper-based surveys (Sue & Ritter, 2007). The survey was designed to be answered within approximately 10 minutes, a length of nine pages representing a medium length survey (Neuman, 2006). The survey ended with "thank you for completing this survey".

The survey includes eight key sections: (1) tracking system capabilities; (2) IT infrastructure; (3) relationship with logistics service provider; (4) firm's integration (covering internal and external firm integration); (5) supply chain visibility; (6) firm's performance (covering firm's performance and competitive advantage; (7) background information; and (8) thank you and final notes. A copy of the survey is included in the appendix J, p.455.

The predominant question type used in this survey was *closed-ended questions* that provided a fixed set of answers. The key advantages to using this pattern include the ease of coding answers for the purpose of statistical analysis, the ease of comparing respondents' answers and for informants, the ease and speed of responses (Forza, 2002; Neuman, 2006). Here, the researcher ensured that the answer's options were mutually exclusive and collectively very thorough (Forza, 2002). The downside of using these type of questions are related primarily to the limited choices that the respondents have. This could cause frustration should the desired answer not be available. However, almost all the closed questions used in this survey were measured on seven-point Likert scale that eliminates the negative side of these type of questions. A seven-point Likert scale was employed (strongly disagree- strongly agree) for interval data measuring the research constructs and in turn to test the research hypotheses developed in chapter five. The use of the Likert scale reduced the likelihood of common method variance (Kumar, Stern, & Anderson, 1993). Open-ended questions were used for a number of questions – these questions represent non-metric or qualitative data- within background and tracking system capabilities sections as the latter is an immature construct requiring some exploratory questions.

Only one contingency question was developed focusing on the relationship between the participant firm and its third party logistics. The respondents were asked to complete this section if applicable or otherwise skip it and move to the following section (Neuman, 2006). To avoid the context effect (a concern in online surveys through the ease of navigation among survey pages), the funnel sequence of questions i.e. organising questions from general to specific was followed when appropriate (Neuman, 2006).

3.5.6 Survey administration

This section is concerned with developing the procedures or the protocol for administering the survey. In collaboration with CIPS the survey was distributed to the targeted affiliated organisations. The method used for distributing the survey was *an email invitation* using CIPS's database. To maintain the anonymity of respondents and to eliminate bias responses, CIPS was responsible for emailing the target respondents. Sue & Ritter (2007) highlight three options for conducting email surveys. *The first option* is to send the survey as an attachment to an email message. This method is not recommended due to the risk of spreading viruses. *The second option* is to include the survey in the email massage. This method is more appropriate for short surveys. Besides, the anonymity concern is violated as the email address is included in the completed survey. The *last option* which is adopted in this research is to embed a link to the survey in the email invitation. Through this method, accessing the survey was more convenient and anonymity of participants was ensured. Creating this link was through subscription to a web-based survey host application (SurveyMonkey) that offered the functionality to develop and manage the survey.

Although it is recommended to contact informants prior to launching a survey (Flynn et al., 1990; Forza, 2002), this was not possible due to the restrictions imposed by CIPS on accessing their members' information. The completed surveys were automatically routed to the researcher. Initial graphs and statistics were automatically created as part of the features of the survey software.

3.5.7 The survey invitation email

The invitation email is the starting point of contact with potential participants. It is a crucial promotional tool given the increasing reluctance of firms and informants to collaborate on another survey (Forza, 2002; Sue & Ritter, 2007). From a social exchange theory perspective, the informant's decision to fill in the survey is mainly based on the extent to which a researcher can convince and motivate them to do so (Dillman, 2000; Klassen & Jacobs, 2001; Sue & Ritter, 2007). The invitation email indicated the collaboration of the Chartered Institute of Purchasing and Supply (CIPS) and the University of Bath in conducting the survey and confirmed that the purpose of the survey was academic not commercial. The invitation email was jointly signed by two senior members of both institutions as that might have a positive impact on the response rate, see appendix C, p.393. The invitation email clarified the purpose of the research as that might also increase the response rate (Turley, 1999). The invitation email was designed to be short but concise (the content of the email is only 112 words). Another concern that was addressed in the invitation email was the confidentiality of participant's responses, which also in turn eliminates response bias.

According to Dillman, Smyth, and Christian (2009), the researcher should *reward participants* whether intangibly in terms of non-material reward such as verbal appreciation or tangibly through material/physical reward or a token of appreciation. The invitation letter provided verbal appreciation of participants' time and effort. The invitation email offered the respondents a summary report of the research as an incentive. For those who were interested in this report, clear instructions were made to leave the name (optional) and the email address at the end of the survey. Since the key informants in this study are middle-level supply chain managers, it might not be appropriate to offer them a monetary or material reward.

Reducing the *cost of participation* is another motivation for the potential participant (Dillman et al., 2009). An email survey is not associated with any form of cost apart from participant's time and effort. The invitation email appreciated the informants' time restraints and assured them that the time required for completing the survey was only approximately 10 minutes.

3.5.8 Increasing the response rate

Attaining high response rates can be a challenge when conducting online survey research (Sue & Ritter, 2007). Hence, follow-up emails were sent to enhance the response rates after launching the survey on Tuesday 18th May 2010 (Kittleson, 1997). Because the survey was distributed through CIPS, the researcher was not able to know who had already completed the survey to send the reminder emails, the only solution was to send reminders to all the sample. The first follow-up email was sent two weeks later (1st June). The third follow-up email was sent one week after the second reminder emails (8th June). The day chosen to send the first and the following two reminder emails was a Tuesday as sending at the beginning or at the end of the week are not recommended. Each of the two follow-up emails included the link to the survey. They also included a statement saying "if you have already completed the survey, then please disregard this email" (Flynn et al., 1990). The final action taken to enhance the response rate was to send personal reminder emails on 22nd June. The last response received came in August 2010.

3.5.9 Response rate

Attaining a high response rate is always a challenge in self-administered surveys, specifically online surveys (Klassen & Jacobs, 2001). A low response rate seems to be a common feature among a substantial number of operations management research (Flynn et al., 1990). In most cases, the response rate in operations management is 20% on average or ranging from 10-20% (Flynn et al., 1990; Malhotra & Grover, 1998). In their study focusing on operations management Klassen and Jacobs (2001) concluded that response rate in online surveys were almost half that of other survey types i.e. 10% or ranging from 5-10%. The key reason beyond this is the reluctance of managers to participate due to survey fatigue (Gofton, 1999). Developments in survey technologies, accompanied by an incremental trend towards survey studies in operations management since 1980 has created this survey fatigue (Klassen & Jacobs, 2001; Rungtusanatham, Choi, Hollingworth, Wu, & Forza, 2003).

Based on a sample size of 800 firms, 129 valid responses were collected; 102 of which were usable cases. As such, the overall response rate is 12.8 which is accepted within operations management research.

3.5.10 Non-response bias

Non-respondents can constrain the generalisability of survey results (Forza, 2002). Another important concern is assessing a non-response bias i.e. to identify any significant difference between a group of non-respondents i.e. late wave respondents and another group of respondents i.e. early wave respondents (Lambert & Harrington, 1990). Non-response bias between respondents and non-respondents means a desirably non-significant difference between the characteristics of the two groups. Hence, two groups were created: the first group represented the responses collected during the first two weeks; the second group represented the responses that were collected after the first reminder email i.e. after two weeks from launching the survey. A comparison between the two groups using the two tailed t-test was held through which all the survey variables were compared ($p<.05$). The results revealed desirable non-significant differences among the variables. Therefore, the absence of non-response bias between early and late respondents was confirmed.

3.5.11 Sample characteristics

Sample characteristics provide an overview about the firms which participated in the survey and in turn informed the research findings. These characteristics might be useful especially when specific conclusions can be drawn relying on these characteristics. In this research, industry type, gross annual sales (see appendix G, p. 396) and firm's size provide the general characteristics of the sample. In addition, some features of firms' tracking systems at the RTAs level were depicted to add further analytical dimensions (mainly the type of logistics service and the type of tracking system). The research now presents the sample characteristics.

Industry type

The research sample is represented through a number of industries. For the purpose of maintaining the power of statistical tests, these industries were compressed into four key homogeneous groups based on the nature of industries as illustrated in table 3-10. Industry type is employed as a control variable that is discussed later within the operationalisation section. Table 3-10 provides the number of firms pertained to each of these industry groups.

Table 3-10: Industry type

Respondent's industry	***Frequency***	***%***
Aerospace, Defence, and Automotive,	20	19.6
Healthcare, IT, Telecommunication, Utilities, Energy	18	17.6
Retail and FMCG	9	8.8
Other manufacturing firms	34	33.3
Missing	21	20.6
Total	102	100

Firm's size

The firm's size was measured based on the number of employees' classified into four key groups ranging from small to quite large firms. Table 3-11 depicts that more than half of the sample (52%) were large and very large firms while 22% of the sample were small and medium size firms. The firm's size is employed as a control variable when investigating the research model.

Table 3-11: Firms' size

Firm's size (employees' number)	Frequency	%
1 – 50	2	1.9
Over 50 – 250	20	19.6
Over 250 – 10000	37	36.3
Over 10000	15	14.7
Missing	28	27.5
Total	102	100

Logistics service

The two main types of logistics service are in-house and outsourcing. In-house service means that a shipping firm uses its own transport fleet to ship products to its customers. Alternatively, outsourcing indicates that logistics activities are performed through 3PL. Some firms might use a mix of the two methods. As shown in table 3-12 the predominant pattern among the sample is outsourcing which comprised 61.8% of the sample. Only 8.8% of the sample follows in-house pattern (see appendix D, p.394).

Table 3-3-12: Types of logistics service

Logistics service	*Frequency*	*%*
In house service	9	8.8
Outsourcing	63	61.8
Both	22	21.6
Others	5	4.9
Missing	3	2.9
Total	102	100

Respondents' characteristics

As previously mentioned in the survey unit of analysis and key informants section (3.5.2, p.80), how knowledgeable and experienced the respondent is determined here by job role, the number of years s/he has held this position along with the period s/he has been working in current firm (Li & Lin, 2006). Drawing on table 3-13 the majority of respondents (76.5%) are middle to high level managers holding the position of supply chain manager (30.4%), senior buyer and procurement/purchasing manager (46.1%). Only 7.8% had different job-titles and those who did not report their position were 15.7%. Thus, the respondents were representative to the predetermined informants' criteria. The average years the respondent had held his/her, position is 4.9 years with a range of 1-20 years. Conversely, the average number of years the respondent had been working in current organisation was 11.5 years with a range of 1 – 41 years. The average period spent whether in current position or firm reflected sufficient knowledge and experience the respondents have that allow them to answer the survey questions.

Table 3-13: Respondents' job title

Job title	***Frequency***	***%***
Procurement/purchasing manager, senior buyer	47	46.1
Supply chain manager	31	30.4
Others (e.g. operations, and logistics managers)	8	7.8
Missing	16	15.7
Total	102	100

3.5.12 Goodness of measures in quantitative research

To evaluate the quality of developed measures in this research, reliability and validity are examined in the following two sub-sections.

Reliability in quantitative research

Reliability means that the numerical results produced by an indicator do not vary because of characteristics of the measurement process or measuring instrument itself (Neuman, 2006). Hence, reliability is mainly concerned with issues of consistency and dependability of measures (Bryman & Bell, 2007). There are two prominent factors that determine the reliability of the measure; stability of measure, and internal consistency of measure. The following section draws on these two types of reliability.

Stability reliability

If the measuring instrument is able to remain constant over time, so it is a stable measure regardless of uncontrollable testing conditions or the respondents state (Sekaran, 2003). The most obvious way of testing the stability of the measure is a test-retest method that implies re-administering the test to the same sample on another occasion (Bryman & Bell, 2007).

Internal reliability

The second dimension of reliability is related to the internal consistency of measures that influences the homogeneity of items constituting a measure that tapes the construct (Sekaran, 2003; Zikmund, 2000). This may require asking several similar (but not identical) questions or presenting a battery of scale items. Although, sub-items measure independently the same concept, the item and its sub-items should act together to constitute an overall meaning. This raises the importance of examining if the items and their subsets in the measuring instrument are highly correlated.

Validity in quantitative research

The most important criterion of research quality is validity and it may be called construct validity (Bryman & Bell, 2007). There are different types of research validity that can be classified into two main categories.

First category is related to assessing the validity of measuring instrument. Here, validity refers to the ability of an indicator, a set of indicators using a scale, or a measuring instrument to measure the concept that they are devised to measure (Zikmund, 2000). The main types of validity within this category are *face validity, content validity, criterion validity (concurrent validity and predictive validity) and construct validity (convergent validity and discriminant validity),* see table 3-14 for a summary of these concepts.

Second category is associated with the integrity of the research findings i.e. evaluating the relevance and precision of research results and evaluating to what extent the finding can be generalised. This category has two main types of validity*; internal validity* that relates mainly to the issue of causality i.e. to assess the extent to which the cause and effect relationship is well established and *external validity* which is mainly to gauge the extent to which findings can be generalised beyond the specific research context (Bryman & Bell, 2007).

Although there are different types of validity, it is not always possible to determine a specific test to each one (Thietart et al., 2001).

Table 3-14: Validity measurements

Validity type	*Concept*
Face validity	The basic type of validity measures that implies judgment by the scientific community determine whether the indicators really measure the construct
Content validity	Assesses the degree to which the full content of the definition is represented in a measure.
Criterion validity	Assesses the validity of an indicator by comparing it with another measure of the same construct in which a researcher has confidence.
Concurrent validity (subtype of criterion validity)	Is proven if an indicator is established with a pre-existing indicator that has already been judged to be valid.
Predictive validity	Is attained if an indicator predicts the occurrence of a future event which is logically consistent to verify the construct's indicator.
Construct validity	Is used for measures with multiple indicators (measuring instruments), asking the question: if the measure is valid, do the various indicators operate in a consistent manner?
Convergent validity (subtype of construct validity)	Is established when the results obtained from two different instruments measuring the same concept are highly correlated.
Discriminant validity (a subtype of construct validity)	Is established when the results obtained from two different instruments measuring different concepts are uncorrelated and should already be predicted as an assumption based on theory.

Source: Adapted from (Bryman & Bell, 2007; Neuman, 2006; Sekaran, 2003).

Goodness of measurement of the survey in this research

Drawing on the previous discussion, the researcher intends to apply suitable tests to assess the reliability of the measuring instruments e.g. Cronbach's coefficient alpha. Practically, the researcher will not be able to apply the test-retest method, split-half reliability method and alternative form reliability methods. Therefore, the researcher will apply suitable tests to examine construct validity and internal validity which will be illustrated within the quantitative analysis chapter (section 6.3.3, p.266).

3.6 Operationalisation of variables

The sequence of measurement process in quantitative research follows a certain order: conceptualisation followed by operationalisation and then actual data collection (Neuman, 2006). In this research, conceptualisation was made through developing clear and rigorous conceptual definitions for the adopted concepts informed by the pilot study findings (see chapter five, p.198). Operationalisation is an operational translation of the defined concepts through developing scales or indicators through which the observed phenomenon can empirically be measured.

For multidimensional concepts, corresponding indicators in the operational definition of each dimension were developed (Forza, 2002). Figure 3-4 presents the key measurement dimensions of each of the independent and dependent variables employed in this research. Well-established measures in existing operations and supply chain literature that have been empirically implemented and tested are used to measure the variables identified in the refined research model (see chapter five, p.198). However, many constructs within operations management area are still immature or not established, so that the researcher has to develop new measures (Forza, 2002; Hensley, 1999). This was the case when developing operational measures for tracking system capabilities as a relatively new concept in operations and supply management. In this research, the five steps followed by Spector (1992) to develop new scales were applied which include: defining the constructs, designing the scale, pilot, testing the scale, conducting item analysis to test if the items constitutes scales.

Because theory is still immature, both academics' and practitioners' views were involved when developing and testing the scales of tracking system's construct (Hensley, 1999). Quality of the created summated scales is confirmed through measuring unidimensionality, internal validity and reliability that will be performed later through the procedures of testing data quality of the measurement instrument (Spector, 1992), see data quality section (6.3.3, P.266).

Based on the theoretical framework, the independent variables and dependent variables were operationalised in the context of supply chain management. Multiple-item scales were adopted and all items were measured on seven-point Likert scale. The following sections discuss the scales through which each of the research variables was measured.

3.6.1 Dependent variables

Two key dependent variables are examined within the refined research model identified in chapter five. First, the impact of asset visibility capabilities in terms of five independent variables including tracking system capabilities, IT infrastructure for supply chain integration, supply process integration, relational orientation with 3PL and internal integration capabilities on supply chain visibility is examined. Supply chain visibility thus is the first dependent variable. Second, asset visibility capabilities that are mediated by supply chain visibility and firm's performance is hypothesised to influence sustainable competitive advantage. Sustainable competitive advantage is therefore the second dependent variable to be measured. The measurement of each of the two dependent variables is explained, respectively.

Supply chain visibility: as illustrated in figure 3-4 supply chain visibility was measured through two main dimensions: the level of information sharing and the level of information quality (Caridi et al., 2009). The measures of each dimension are elaborated in turn.

Level of information sharing: level of information sharing indicates the quantity and the scope of information exchanged between supply chain partners (Caridi et al., 2009). Based on a review of the supply chain literature, information sharing is widely discussed and examined inductively through qualitative methods, mainly case studies e.g. Barratt and Oke, (2007), Kaipia and Hartiala, (2006) and Caridi et al., (2009). Other studies adopted a deductive approach using a simulation method to assess information sharing e.g. Lin, Huang, and Lin, (2002). Few studies have assessed information sharing through developing a multidimensional scale such as Li and Lin, (2006). This research principally followed the items developed by Li and Lin, but based on the pilot test interviews and a review of the literature another three items were added. Using a six-item scale, the participants were asked to respond to what extent their supply chain trading partners: (1) are informed in advance about changing needs; (2) share proprietary information with them; (3) keep them fully informed about issues affecting your business processes with them; (4) share business knowledge of core business processes with them; (5) exchange information that helps establish business planning; and (6) inform each other about changes that may affect the other partners.

Level of information quality: In their study, Lee, Strong, Kahn, and Wang (2002) draw on various studies that investigated information quality measures such as Wang and Strong, (1996), Wand and Wang, (1996), Zmud, (1978) and Delone and McLean, (1992). They then provided fifteen indicators for information quality e.g. completeness, believability, consistent representation, relevancy, interpretability, freeness-of-error. In addition, Nelson, Todd, and Wixom (2005) adopted completeness, accuracy, format and currency as key indicators for information quality. In the context of supply chain management, Li and Lin,(2006) developed a five-item scale for measuring the quality of information exchange between supply chain partners related to timing, accuracy, completeness, reliability and adequacy. The research predominantly adopted the Li and Lin' measures and added another three indicators based on a review of the literature and pilot test interviews. Therefore, an eight item scale was developed and respondents were asked to answer to what extent information exchange between their supply chain trading partners and them was: (1) timely; (2) up to date; (3) generated frequently; (4) accurate; (5) valuable and applicable to specific tasks; (6) consistently presented; (7) easy to understand; and (8) interpretable.

The scales for both information sharing and information quality were anchored from "strongly disagree" to "strongly agree".

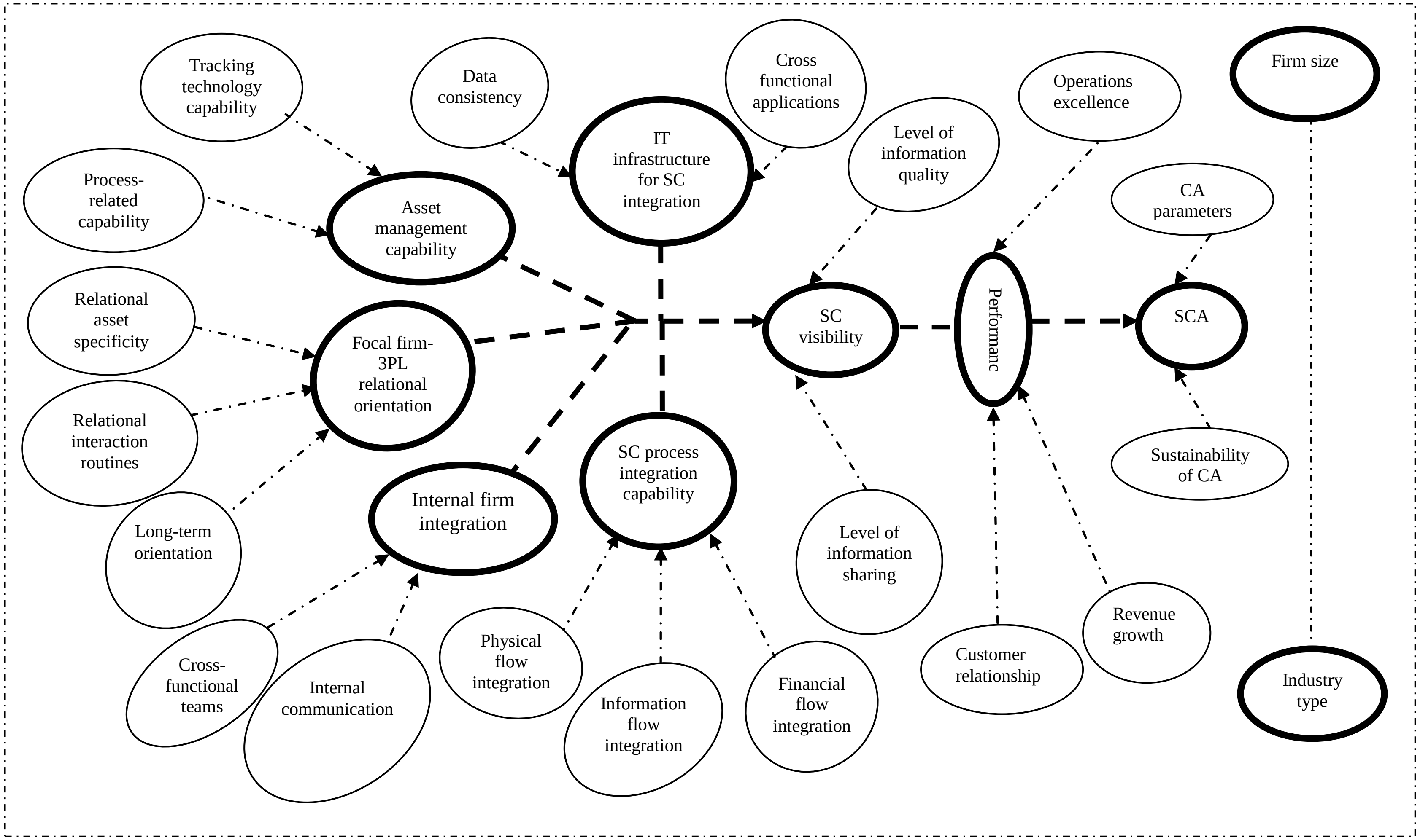

Figure 3-4: Operationalisation of the research variables

Sustainable competitive advantage: it is argued that in the context of RBV, competitive advantage as a dependent variable should be gauged through two indicators: competitive parameters and time frame of holding a competitive position (Wade & Hulland, 2004). As seen in figure 3-4 two key elements encompass sustainable competitive advantage: competitive advantage parameters and sustainability of competitive advantage each of which have their own dimensions. According to Li, Ragu-Nathan, Ragu-Nathan, and Subba (2006a), competitive advantage parameters incorporate price/cost, quality, delivery dependability, production innovation and time to market; whereas, sustainability factors are measured through two summated scales: return on total assets and return on sales over consecutive three years (Bhatt & Grover, 2005; Fahy, 2003). The research elaborates, each element respectively and its associated dimensions.

Competitive advantage parameters: the research employed the multi-item scale used by Li, Ragu-Nathan, Ragu-Nathan, and Subba, (2006a) to assess competitive advantage. The authors built this comprised scale based on previous study on competitiveness such as Porter, (1985a), Stalk, (1988), Tracey, Vonderembse, and Lim, (1999), and Kessler and Chakrabarti, (1996). The five dimensions of competitive advantage comprised price/cost, quality, delivery dependability, production innovation and time to market. As such, using a fourteen-item scale that ranged from "strongly disagree" to "strongly agree", the participants were asked to compare their firms to their competitors when responding the following statements: they are able to: (1) offer competitive prices; (2) offer prices as low as or lower than their competitors; (3) compete based on quality; (4) offer products that are highly reliable; (5) offer products that are very durable; (6) offer high quality products to their customer; (7) deliver customer orders on time; (8) provide dependable delivery; (9) alter their product offerings to meet client needs; (10) respond well to customer demand for new features; (11) deliver the product to market quickly; (12) be the first in the market in introducing new products; (13) maintain a lower time-to-market than industry average; and (14) have fast product development. The corresponding items to the five dimensions of competitive advantage are as follows: Price/cost items 1, 2; quality items 3-5; delivery dependability items 6, 7; product innovation items 8, 9; time to market items 10-14.

Sustainability of competitive advantage: the research drew on studies by Fahy (2003) and Bhatt and Grover, (2005) to gauge sustainability of competitive advantage. As such, return on total assets as well as return on sales was measured over three consecutive years (2007, 2008 and 2009). Using a six-item scale that ranged from "significantly lower" to "significantly higher", the respondents were asked to compare themselves to their major competitors with regards to: (1) return on total assets in 2007; (2) return on total assets on 2008; (3) return on total assets on 2009; (4) return on sales in 2007; (5) return on sales in 2008; and (6) return on sales in 2009. The next section clarifies the operationalisation process of the independent variables and is followed by the operationalisation of control variables.

3.6.2 Independent variables

This section highlights the measurement process of the independent variables. Drawing on the refined research model illustrated in chapter five (section 5.4, p.235), six antecedent variables comprising asset visibility capabilities were adopted including tracking technology capabilities, process-related capabilities, IT infrastructure for supply chain integrations, supply chain process integration, relational orientation with 3PL and internal integration. In response to the research model, these predictors were first regressed against supply chain visibility and then against sustainable competitive advantage. Since supply chain visibility worked initially as a dependent variable it was operationalised in the previous section. Each independent variable will now be discussed in turn.

Tracking technology capabilities: tracking technology capabilities as a relatively new concept in supply chain management does not have well established measures. As previously mentioned, to develop such new measures, the research followed the procedure of creating a new scale based on Spector, (1992). The construct was therefore initially conceptually defined in the light of key features of good asset management practices in tracking and tracing systems especially RFID as a key example (e.g. Aberdeen-Group, 2004; Lampe & Strassner, 2004; Martinez-Sala et al., 2009; Ngai, Cheng, Lai, Chai, Choi, & Sin, 2007b; Tajima, 2007). The new measures went through an extensive piloting trail as discussed in section 3.5.4 (survey pilot testing), p.83. In this process, one item was removed due to overlapping with another item and rephrasing of the item was considered. Using a four-item on seven-point Likert scale, the respondents were asked to indicate the extent to which they agree or disagree with the following statement: their tracking systems for their core product help them to: (1) track RTAs on an individual basis across their supply chain; (2) locate specific RTAs across their supply chain; (3) identify current physical status of their RTAs; and (4) maintain historical information of RTAs used within their supply chain.

Process-related capabilities: as a core component of a tracking system, process-related capabilities were developed as a non-technological factor related mainly to logistics process, in particular transport logistics. Process-related capability is another new concept within supply chain visibility. Lai, Ngai, and Cheng (2004) claim that there is a lack of research in developing measures of supply chain performance related to transport logistics function. Kleinsorge, Schary, and Tanner (1991) reported that transport logistics performance measures should focus more on intangible aspects than physical ones. According to Barney and Hesterly, (2006) the intangible dimension of a resource reflects its capability. As such, performance measures may also indicate capability measures.

Again using the procedure of developing a new scale by Spector (1992), the construct of process-related capabilities was conceptually defined based on the study by Becker, Vilkov, Weib, and Winkelmann, (2009). The study adopted a process driven business value perspective and the authors drew on the process-related benefits or capabilities associated with the use of advanced tracking system specifically RFID. These capabilities comprise *processing time reduction, error reduction, resource consumption reduction, and information process*. The research treated these four dimensions as the capabilities associated with logistics process that were influenced by tracking technology, see figure 3-4. Each of these dimensions were gauged through a multiple-item scale.

To create these measures the research was influenced by the supply chain operations reference (SCOR) model developed by the supply chain council as a strategic tool in helping senior managers to simplify the complexity of SCM (Huan, Sheoran, & Wang, 2004). SCOR model is the first cross industry framework for assessing and improving supply chain performance (Wong & Wong, 2008). This model sees supply chain as a chain of processes and offers four components that link various organisational processes: plan, source, make and deliver (Stewart, 1995). The model provides the main criteria for measuring each component based on four supply chain- related aspects: reliability, responsiveness (flexibility), costs and assets. SCOR considers delivery and transport logistics practices. This model provides performance measures for all associated parties in transport logistics i.e. shipper, 3PL and consignee through a systematic approach that assesses performance on a supply chain level not an individual firm level (Lai, 2004; Wong & Wong, 2008). Performance measures of the transport logistics process from the shipper's firm perspective provided a useful guide for developing the logistics capabilities scale. Pilot test interviews were then conducted with practitioners and academics to refine these measures. Appropriate changes were made whether related to content or wording.

A twelve-item scale was developed and the respondents were asked to indicate the extent to which they agree or disagree with the following statements: their tracking systems for their core product help them to: (1) reduce delivery time to their customers; (2) reduce return time of empty RTAs; (3) maintain continuous flow of products across their supply chain; (4) reduce delivery errors to their customers; (5) reduce return errors of empty RTAs; (6) maintain quality of their products across supply chain operations; (7) reduce waste associated with time and money; (8) improve security aspects e.g. loss, counterfeiting and theft; (9) reduce inefficient consumption of their resources; (10) minimise errors in data capture; (11) provide accurate information e.g. check out/in activities; and (12) provide updated information e.g. expected delays, route change. The corresponding items to the four dimensions of process-related capabilities are as follows: processing time reduction items 1-3; error reduction items 4-6; resource consumption reduction items 7-9; information process items 10-12.

IT infrastructure for supply chain integration: valid measures were used to assess IT infrastructure for supply chain integration construct. According to Rai, Patnayakuni, and Seth, (2006), two sub-constructs constitutes IT infrastructure for supply chain integration including: data consistency and cross-functional supply chain management application systems integration.

Data consistency was gauged based on three-item scale. The participants were asked to state the extent to which they agree or disagree with the following statements: their IT infrastructure (1) support the use of automatic data capture systems across their supply chain; (2) allow common definitions of key data elements across their supply chains; and (3) offer consistency in storing the same data in different databases across their supply chains.

Cross-functional SCM application system integration was measured using a four-item scale. The respondents were asked to refer the degree to which they agree or disagree with the following statements: in their supply chain (1) planning applications are able to be communicated in real time; (2) transaction application are able to be communicated in real time; (3) customer relationship applications are able to be communicated with internal applications of their firms; and (4) supply chain applications are able to be communicated with internal applications of their firms.

Supply chain process integration capabilities: following the valid measures developed by Rai, Patnayakuni, and Seth, (2006), supply chain process integration capabilities were measured through three sub-constructs including physical flow integration, financial flow integration and information flow integration. Each sub-construct was measured through a multi-item scale. Based on pilot testing interviews and a review of literature e.g. Li and Lin, (2006) and Frohlich and Westbrook, (2001) two items were added to information flow integration as a sub-construct.

Using a thirteen-item scale, respondents were asked to determine the degree to which they agree or disagree that across their supply chains: (1) accounts receivable processes are automatically triggered when they ship to their customers; (2) accounts payable processes are automatically triggered when they receive supplies from their suppliers; (3) inventory holding is minimised; (4) supply chain-wide inventory is jointly managed with your suppliers and their logistics partners; (5) suppliers and logistics partners deliver products and materials just in time; (6) distribution networks are configured to minimise total supply chain-wide inventory costs; (7) production and delivery schedules are shared; (8) performance metrics are shared; (9) supply chain members collaborate in arriving at demand forecasts; (10) downstream partners share their actual sales data with them; (11) customers give them feedback on quality and delivery performance; (12) demand levels are visible; and (13) inventory data are visible at all stages. The corresponding items of each of the three sub-constructs are as follows: financial flow integration items 1, 2; physical flow integration items 3-6; information flow integration items 7-13.

Relational orientation with 3PL: the measures used to assess relational orientation with 3PL relied mainly on the valid scale adopted by Patnayakuni, Rai, & Seth, (2006) with a special focus on 3PL. The authors investigated the relationship between relational orientation of the focal firm and information flow integration with its supply chain partners. In this research, other studies were considered that have developed and validated measures for inter-organisational governance and 3PL-focal firm relationship such as Wang & Wei, (2007), Panayides & So, (2005), Handfield and Bechtel (2002), Li et al., (2006a). Three key sub-constructs including *relational asset specificity, relational interaction routines and long term orientation* reflected relational orientation with 3PL. Each sub-construct was represented through a multiple-item scale. Based on a review of literature and the pilot testing interviews, four items were added to the relational interaction routines and another one item to long-term orientation as sub-constructs.

A fifteen-item scale was developed on 1-7 likert scale from “strongly disagree” to “strongly agree”, the participants were asked to focus on their major transport logistics service provider and indicate the degree to which they agree or disagree with the following statements: their key logistics service provider (1) have created formal and informal arrangements for information exchange; (2) is involved in quality and improvement initiatives; (3) share best practices; (4) help them to learn about new technologies and markets; (5) are involved in developing their logistics processes; (6) have planned to anticipate and resolve operative problems; (7) have developed ways to improve cost efficiencies; (8) have a dedicated team for your continuous replenishment program (CRP) or other efficient consumer response (ECR) practices; (9) have customised tools and machinery to their needs; (10) have dedicated significant investment and capacity to their relationship; (11) have knowledge about them that is difficult to replace; (12) have a long-term relationship; (13) manage their relationship based on trust which is more significant than a formal contract; (14) they do not take any intentional actions that can hurt their relationship; and (15) have jointly established goals. The corresponding items to each sub-construct are as follows: relational interaction routine items 1-8; relational asset specificity items 9-11; long term orientation items 12-15.

Internal integration capabilities: In their study of the organisational antecedents of a firm’s supply chain agility, Braunscheidel and Suresh, (2009) adopted valid measures for internal integration based on the previous work done by Pagell, (2004). In this research, these valid measures are employed.

Using eight-item scale, the respondents were asked to focus on their firms’ internal integration practices and indicate the extent to which they agree or disagree with the following statements: (1) all departments are connected by a single central information system; (2) cross functional teams to solve problems are used; (3) communications from one department to another are expected to be routed through proper channels; (4) internal management communicates frequently about goals and priorities; (5) openness and teamwork are not encouraged (reversed scored); (6) when problems occur, finding someone to blame is more important than finding a solution (reversed scored); (7) formal meetings are routinely scheduled among various departments; and (8) when problems or opportunities arise, informal, face-to-face meetings never occur (reversed scored).

Firm performance: valid measures were adopted to assess firm performance that were developed and validated by Rai et al., (2006). Three sub-constructs constituted firm performance construct including: operational excellence, customer relationship and revenue growth. Using a multiple-item scale each of these sub-constructs was assessed.

A seven-item scale was developed and the respondents were asked to focus on their firms performance and state to what extent they agree or disagree with the following statements: their firm (1) shortens their products delivery cycle time; (2) offers timeliness of their after sales service; (3) improves their productivity level; (4) keeps a strong and continuous bond with their customers; (5) has precise knowledge of their customer buying patterns; (6) increases sales of their existing products; and (7) finds new revenue streams e.g. new products, new market. The corresponding items to each sub-construct are as follows: operational excellence items 1-3; customer relationship items 4, 5; revenue growth items 6, 7.

3.6.3 Control variables

A control variable is defined as “a variable that is held constant or whose impact is removed in order to analyse the relationship between other variables without interference” (Dohrman, 2009). Therefore, to ensure robustness of the results and to enhance its interpretation, control variables were employed to remove their effect on the hypothesised relationships. In this research two control variables were employed: firm size and industry type. The research draws on both variables in turn.

Firm size: it is claimed that the larger the firm, the greater the opportunity to achieve better performance due to more resources and higher IT capabilities (Hitt, Wu, & Xiaoge, 2002). Hence, larger firms are more likely to adopt new technologies in comparison to small and medium size enterprises (SMEs) that might influence the hypothesised relationships (Harland, Caldwell, Powell, & Zheng, 2007). Consequently, in this research, firm size based on number of employees was controlled.

Industry type: Drawing on the research sampling frame, various types of industries were considered to enhance the replicability of the study (Forza, 2002) (see sampling frame section, p.77). However, having a variety of industries would also mean variability in processes, competitive forces, work force management etc. that might have an impact on the hypothesised relationships. It is argued that “controlling industry effects can compensate for variability between industries” (Flynn et al., 1990). Thus, industry type was controlled in the research model.

3.7 Summary of the chapter

This chapter explained the research philosophical and methodological stances through which the research objectives can be achieved. The chapter began by discussing the philosophical considerations of social research, demonstrating that the research philosophical decisions inform the research logic and approach. Additionally, the chapter highlighted the practical considerations of social research; and how the research methodological decisions were taken. These decisions are concerned with research strategy and time horizon which give rise to decisions about data collection approach, data collection techniques, sampling and units of analysis. Furthermore, data quality issues as well as the operationalisation of variables were discussed.

The following chapter illustrates the key findings of the pilot study that investigated the first stage of the research conceptual model. It also highlights the key data quality issues pertaining to this stage.

Chapter 4: Tracking and tracing systems: an overview & pilot findings

4.1 Introduction

This chapter provides an overview on tracking and tracing systems before introducing the pilot study findings, see figure 4-1.

With respect to tracking and tracing systems, this chapter starts by illustrating the concepts and the different perspectives of tracking, traceability and visibility (4.2). The chapter then draws on some examples of tracking applications (4.3). The problems related to poor tracking practices that businesses encounter are then explained (4.4). This is followed by discussing business problems associated with poor RTAs tracking practices as the key focus of this study (4.5). The merits of tracking, tracing and visibility are highlighted with a special focus on those related to RTAs (4.6, 4.7). The chapter then demonstrates in detail the key types of tracking systems incorporating low-tech and high-tech tracking systems (4.8). The chapter then presents examples of integration and coupling of tracking applications (4.9, 4.10), before summarizing the tracking technologies (4.11). Finally, a summary of the chapter are provided (4.16)

In considering the pilot study findings, the chapter highlights the procedures employed to ensure the quality of the pilot study data (4.12). In addition, the strategies and techniques for pilot data analysis are discussed (4.13). The context and relevant background of the case organisation are presented as well as detail of the sub cases (4.14, 4.15). The key findings of the pilot study are illustrated (4.16).

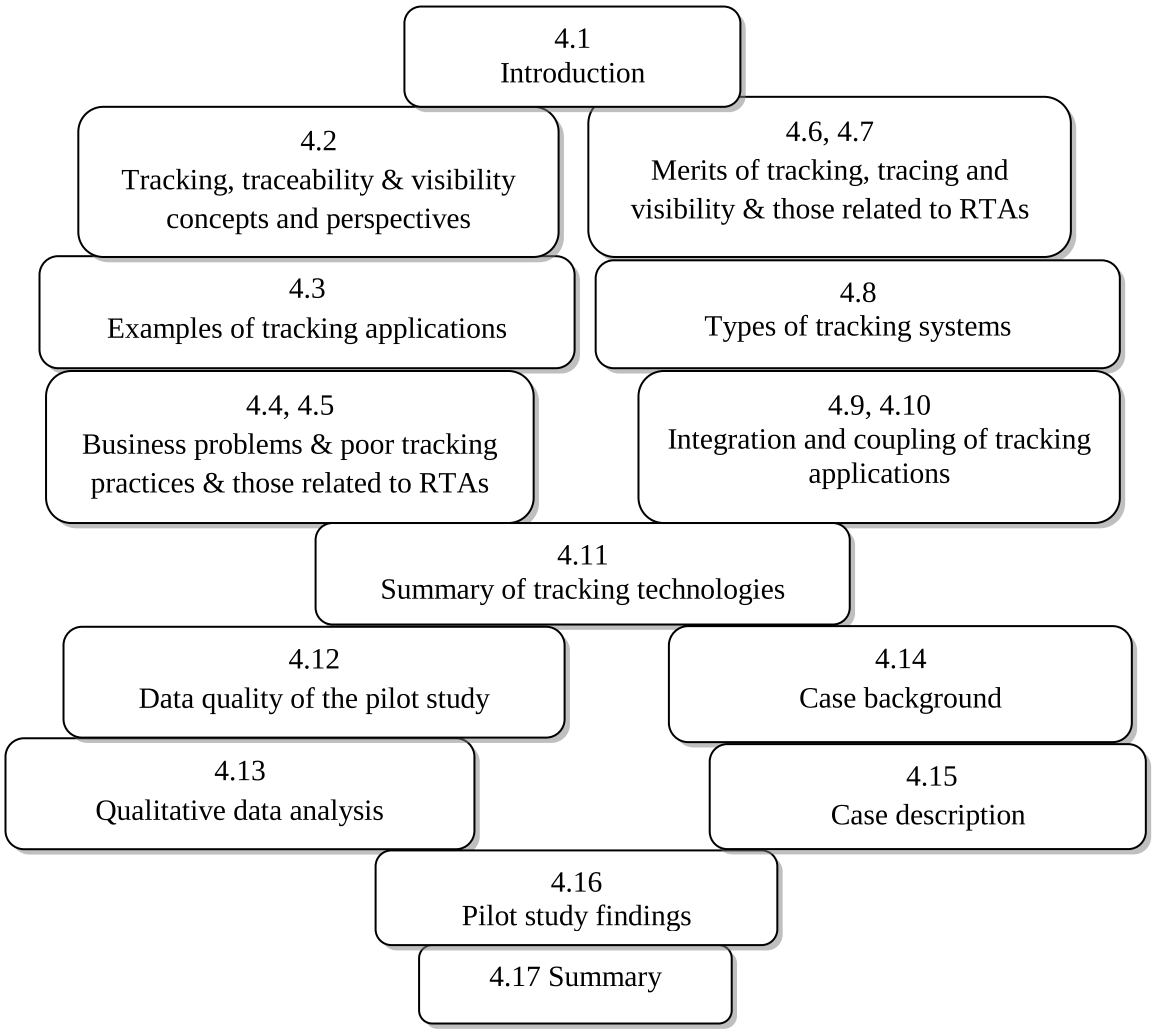

Figure 4-1: Structure of chapter four

4.2 Tracking, traceability and visibility: concepts and perspectives

Tracking and traceability are integrated concepts not interchangeable ones; the latter is more comprehensive. It is stated that tracking is "*the ability of a company to determine the state of part at present*", whereas tracing is "*the ability to tell with certainty what the state the part was in, in the past*" (Kelepouris et al., 2006b; Rönkkö, Kärkkäinen, & Holmström, 2007). The state of a part or an object is related to its identity, location, operational condition and maintenance history. Traceability has become prominent as it is a requirement within ISO9000/BS 5750 quality procedures that means "*the ability to retrace steps and verify that certain events have taken place*" (Cheng & Simmons, 1994). Traceability data facilitate the ability to tell with certainty what the previous state of an object is (e.g. where the items come from, previous processing, their contents, previous maintenance condition, compliance to quality and environmental standards).

Tracking and traceability concepts shift the business focus of asset and material management from location-based control to asset tracking and item-centric materials (Rönkkö et al., 2007). This means that the asset or the item itself becomes the target of control rather than asset and inventory accounts in predefined sites (Holmström, Kajosaari, Främling, & Langius, 2009). Tracking and traceability at an object level rather than the bulk/batch level is triggered by the evolution of data capture technology and Auto-ID applications.

Cheng and Simmons (1994) propose three key functions of tracing including the ability to detect status, to check progress against the schedule or plan, and to inform decision-making. Tracking and traceability data are not an end in themselves but they are means to the end. As such, traceability data are only beneficial if they are communicated to support business decisions. Visibility is a step further as it encompasses the ability to communicate and share tracking and traceability data in a way that can ensure their quality (e.g. availability, accuracy, frequency) for better business decisions. The extent to which tracking and traceability data are communicated and shared reflects the level of information visibility.

Van Dorp (2002) differentiates between a restricted and an extensive scope of tracking and tracing concepts. In the *restricted scope*, tracking and tracing "provides the visibility to where work is at all times and its disposition" that can optimise operational performance. On the other hand, the *extensive scope* of tracking and tracing encompasses the restricted view and expand to cover supply chain optimisation.

Various perspectives and in turn different objectives are beyond the implementation of tracking and tracing systems. The following section, discusses these perspectives.

4.2.1 Individual firm perspective

In considering the individual firm perspective, tracking and traceability practices are mainly implemented to optimise the performance of firm's internal operations. Here, tracking and traceability is about assets or objects that are managed by an individual firm that usually has a full control of these assets e.g. products, handling tools, constructions kits, employees records, medical devices, equipment and workforce.

In considering individual manufacturing organisations, tracking and traceability incorporates two structural dimensions: *horizontal* and *verti*cal. The former dimension is concerned with tracking and tracing at an operational level including production as a main operational function and other supporting functions such as finance, supply and purchasing, human resource, and warehousing. In this respect, tracking and traceability is known as a horizontal topic due to the huge focus on this dimension (van Dorp, 2002). On the other hand, the vertical dimension of tracking and tracing addresses various management levels including strategic, tactical, and operational that influence different objectives and in turn, different types of tracking and tracing data (Cheng & Simmons, 1994). At an operational level, the main objectives are to reduce inventory, improve quality, and streamline operations, etc., whilst at a tactical level, the main goals are associated with the provision of a new product, the output of products, and the use of new technology. Traceability goals at a strategic level are related to growth rate, market share and profit.

With regard to hierarchical structure, tracking and tracing in multi-site plants, managed by individual firm, are more complicated as a higher degree of visibility is needed to inform business decisions considering vertical traceability incorporating operational, tactical and strategic management levels.

In manufacturing, tracking and traceability are established to ensure continuous replenishment of production supplies and raw material for continuous flow of operations. At an operational level, tracking and tracing deal with buffer stock, batch size, physical condition and availability of machines and equipment, whilst at a tactical level (i.e. planning and design) tracking and traceability focus on current performance of operational level, work-in-process, resource utilisation, scrap and rework level, etc. (Cheng & Simmons, 1994). Strategic tracking and tracing is concerned with current performance of tactical level, demand level, government regulations and environmental legislations.

Tracking and traceability are also used for different purposes in other business sectors. Here are some examples for tracking practices driven basically by internal firm’s perspective. In medical care centres and hospitals, tracking and tracing systems may be used to ensure that the right drugs and treatment are given to the right patient. Tracking system may be used in construction, mining, infrastructure and facilities companies to enhance visibility of offsite operations. In airports, tracking and tracing are used to track and trace passengers' luggage. In libraries, tracking and traceability helps in monitoring the borrowing records, check-in/out and the availability of books and other resources. For security and safety concerns, human tracking and identification systems are implemented in various organisations.

4.2.2 Supply chain perspective

With respect to network structure, tracking and traceability practices are mainly related to assets/objects that span firms' boundaries and are managed by more than one organisation in a value chain. The extensive definition of tracking and tracing fits well within this view, so that the key purpose is to optimise the performance of supply chain operations based on better information visibility. In this respect, tracking and traceability might deal with materials flow from suppliers to end users at an operational level (day-to-day operations and transactions) that might expand to cover tactical (planning and control) and strategic (long-term objectives) levels. In considering business-to-business context and the interdependent nature of organisations linked in a value chain, supply chain actors need to decide about the scope, mechanism and requirements of tracking and tracing. From an individual firm view, tracking and tracing at an internal operational level are significant for continuous flow of operations, so that in most cases, they are mature and well-managed. In considering a supply chain perspective, tracking and tracing are also significant for the streamlining and smooth flow of supply chain operations. However, in the current business environment, the managerial practices of tracking and tracing among firms in a value chain are still immature and driven mainly by financial flow activities i.e. the progress of orders.

As previously mentioned, communicating tracking and tracing data are essential to attain visibility and in turn to inform business decisions. Thus, information architecture is the key mechanism to attain visibility. Attaining visibility at a supply chain level requires a certain level of integration that ensures the compatibility of standards and information architecture of applications between supply chain trading partners. Further discussion about different tracking applications is provided within section 4.8.2, p.147.

In considering mass-distribution constraints, the trend towards reusable packaging and the current features of transport logistics including the predominance of DCs, consolidations of product and merge in transit, tracking and traceability of physical flows are in most cases at RTAs level. Tracking and traceability mechanism at this level facilitates tracking and tracing of products carried in RTAs. In addition, this mechanism should ensure the availability and reliability of RTAs for continuous and smooth flow of supply chain operations (Ilic et al., 2009b; Johansson & Hellström, 2007). With respect to a supply chain perspective, RTAs have special features that differentiate them from generic physical assets (GPAs) managed by individual firms. Table (4-1) provides a comparison between RTAs and GPAs.

Table 4-1: GPAs versus RTAs

Item of comparison	*GPAs*	*RTAs*
(ownership[*] and management)	The owner/renter is the same user who manages assets individually. Here, ownership is not separate from management.	One owner/renter and multiple users who share the responsibility of managing assets. Here, ownership is separate from management.
Asset's nature	Static and mobile	Mobile
Asset's function	Mainly an operating tool used to produce service or physical product within one organisation.	Mainly transport mean spanning firms' boundaries used to carry physical products to their destinations.
Scope of asset's function	May cover one or more processes/stages within firm's internal operations	May cover multiple stages across a supply chain starting from raw materials to end customer.
Asset management main objective	Mainly to enhance assets' reliability	Mainly to enhance assets' availability
Asset management focus	Mainly to optimise assets' life focusing on maintenance strategy to meet performance standards.	Mainly to track and trace assets' location to enhance SC performance.
Logistics network scope	Basically used in forward logistics or in reverse logistics	Used in both forward and reverse logistics
Significance of inter-firm relationships	Influential and implicit	Highly influential and explicit
Significance of intra-firm	Highly influential and	Influential and implicit

[*] Owner refers to both ownership and renting style

relationships	explicit	
Effect on SC performance	Significant and indirect	Crucial and direct
Asset's design	May be complex, complicated, or simple	Mainly simple
Tracking technology	Significant for asset's reliability	Significant for asset's availability

Source: prepared by the researcher

4.2.3 External environment perspective

The external environment is a powerful trigger for tracking and tracing initiatives that may fit more within business-to-consumer context. The external environment’s effects are influenced by various elements including the pressure of governmental and environmental legislations, quality certifications, sustainability issues, and ethics and authenticity concerns (New, 2010). Different parties constitute business external environment such as governing institutions, authorities and any other external stakeholders. In his work, Van Dorp (2002) gives examples of the environmental legislations employed by European Economic Community (EEC) and how tracking and tracing are significant to comply to these legislations.

Packaging and packaging waste should be managed in a way that can prevent or eliminate any harmful effect on the environment. This entails reducing the use of non-returnable packaging material, which supports the trend towards reusable packaging, while increasing the amount of recycled packaging material. Tracking and tracing systems participate in reducing the environmental impact of packaging material through monitoring its quantity and type.

The functional labelling of products is to provide consumers with the basic information about the product including minimum durability, the content/composition of the product, instructions for storage, preparation and usage for safety purpose, the origin/provenance and the authenticity. This information must be accurate to enhance traceability of quality.

The official control of foodstuffs is the aspect related to verifying quality, composition rules and legislations compliance. The inspection of foodstuffs is concerned with food additives, trace elements, mineral salts, packaging materials, etc. Competent authorities carry out regular and irregular ad hoc (e.g. in the case of non-compliance is suspected) inspections.

Liability for defect products is a regulation associated with the responsibility of the manufacturers for problems or damages due to defectiveness of their products. This regulation protects consumers from any harm or damages resulting from defective products. Here, tracking and tracing are significant to identify the producer and may be the distributor of the defective products. Failing to assign the liability for damage or harm means that all suppliers of the product share the responsibility.

There is a growing awareness among consumers and nongovernmental organisations (NGOs) -interested in consumer's protection and environmental issues- in sustainability and greener operations, business ethics and authenticity of products. This puts more pressure on companies to improve the way they manage their operations to efficiently respond to these needs. In this respect, products' traceability data is of interest. Companies that are able to offer product tracking and traceability information that can be visible by customers can gain a number of advantages over their peers e.g. enhanced market share/sales, better image and reputation, higher credibility, etc.

4.3 Examples of tracking applications

Table 4-2, shows various business aspects that use tracking systems to better manage specific operations and activities considering indoor and outdoor applications.

Table 4-2: Example of tracking applications

Tracking areas	*Examples of tracking applications*
Manufacturing	Inventory management, tracking manufacturing processes, quality control and resource/asset management.
Warehousing	Picking, receiving and shipping management.
Transportation	Distribution process (e.g. logistics tracking, monitoring vehicles, delivery security), public transport, toll collection, smart keys for cars, automatic vehicle location, rail tracking, truck monitoring, tracking courier parcels, reusable asset tracking, tracking equipment data (e.g. forklifts and their batteries), air transportation and luggage handling and parcel delivery.
Retailing	Shelf-stock management, inventory management and checkout process, security purposes
Healthcare	Tracking equipment and personnel, safety practices, patient medical records, pharmaceutics.

Perishables & food products	Load processing, auction, ingredient/recipe control.
Human identification	Digital ID, electronic passport, building access, safety and security.
Finance	Banknote identification and credit cards.
Libraries	Tracking resources, security, finding misplaced items, monitoring borrowing/return records, self-check in/out.
Digital documents	Digital signature, access/revision control and monitoring of documents.
Environment	Industrial/non-industrial waste management and recycling.
Agriculture	Livestock tracking, and crop identification
Military	Military logistics
Clothing	Cleaning control and laundry tracking
Fuel and chemicals	Dispensing management
Sports	Sports events' management e.g. timing and results, tracking balls and gaming chips

Source: adapted from Ilie-Zudor et al. (2011).

4.4 Business problems and poor tracking practices

The core of asset tracking and tracing is to make assets available and reliable to do their jobs. Businesses including services and manufacturing encounter substantial problems in managing their operations and supply chain activities due to unavailability and/or unreliability of assets. Shrinkages, breakdowns, and/or poor physical and non-physical (e.g. non-conformance to business ethics, unauthentic products) conditions of assets could occur for many reasons. These include misplacement, theft, damages, counterfeiting, delays, messy workplace, inefficient maintenance practices, poor communications, fraudulent, or human errors. The consequences of this might be crucial in some business sectors such as healthcare (e.g. unavailability of medical tools used in ambulances or in surgeries might lead patient mortality). This is also the case in other sectors that directly affects people' health and wellbeing. For example, failing to track and trace the physical conditions of perishables and food products may lead to fatal health problems. In the retail industry, shrinkage in on-shelf products annoys consumers. Customer's dissatisfaction may also happen due to delays in receiving the service or product, violating regulations, standards and ethics that might end up with dispute and prosecution.

Unavailability of assets leads to stoppages and bottlenecks within internal firm's operations and across its supply chain. Finding or replacing missing assets is time consuming and costly. In manufacturing, failing to set up efficient track and trace procedures to monitor the physical condition of tools and equipment results in unexpected stoppages and in turn costly bottlenecks and delays.

Another example is related to off-site operations (e.g. constructions, infrastructure, and mining industries) in which tools and equipment are in move. Here, unavailability of one of these items may result in the whole job being stopped. This is translated into high costs due to delays, setup and re-setup cost, inefficient use of company's resources, excessive overhead cost (e.g. security, rent, maintenance) and bad reputation.

Here is a summary of some aspects of the problems companies encounter due to poor tracking and tracing practices.

- High cost of lost assets;
- Operations' delays and costly rescheduling arrangements;
- Supply chain disruption leading to late deliveries and lost sales;
- Irrational inventory practices resulting in costly stockpiles/stock-out;
- Wasting time and money to find or replace missing assets;
- Bad reputation, disputes and financial and/or legal penalties/compensations due to breaching safety, ethical and/or authenticity regulations, quality and/or environmental standards or contractual agreements;
- Diminished asset life;
- Inefficient use of companies' resources;
- Customer dissatisfaction.

4.5 Business problems and poor RTAs tracking practices

Nowadays, the use of RTAs has become necessary due to environmental legislation and commercial imperatives (Bowman et al., June 2009; Wu & Dunn, 1995). It is contended that current RTA tracking and tracing practices result in poor asset visibility across SC transport logistics activities (Johansson & Hellström, 2007; McFarlane & Sheffi, 2003). Table (4-3) indicates the key problems resulting from poor asset visibility throughout SC transport logistics operations including shipping, transportation, receiving, and internal firm operations.

Table 4-3: SC problems within transport logistics

Process	*Supply chain problems*
Shipping	Late orders, lack of transportation capacity exploitation, lack of visibility for actual order completion, misplaced and wrong picked RTAs/items.
Transportation	Delays, misrouted RTAs in terminal operations, drop-off and pick-up errors, spoilage, pilferage during transit, last minute diversion of the conveyances, dynamic trucking operations.
Receiving	Wrong delivered items, shortages of items, wrong quantities, wrong location deliveries, data entry errors, wrong put-away activities.
Internal logistics activities	Manual, error-prone process, high labour cost, out of space storage facilities, stockpiles and stock-out, manufacturing outages, inefficient use of field engineers' time and budget due to unavailability of items/RTAs, high cost of emergency orders of unavailable items, fines for late delivery, etc.

Source: adapted from; (GS1UK, 2011; McFarlane & Sheffi, 2003; Roussos, 2006).

It is estimated that retailers in North America alone lose more than $200 billion every year because of counterfeits especially those related to in-transit from suppliers to retailers, whilst according to NRF (National Retail Federation) return fraud costs are nearly $14 billion each year (Ennovasys, 2011a). GS1 UK[8] has reported the following statistics associated with current asset management practices (GS1UK, 2011).

- 50% of organisations use manual asset management systems
- 50% of organisations spend at least 5% of revenue on their logistics asset operations, while 7% of organisations consume more than 10% of revenue on these operations.
- 25% of organisations lose 10% or more of their asset (container) fleet each year due to damage, thefts, and misplacement.
- 75% of organisations indicate that current asset management systems are not able to achieve their operational goals largely because of poor asset visibility.
- 66% of firms seek solutions to improve their asset management systems and in turn asset visibility.

[8] "*GS1 founded in 1977, GS1 is an international not-for-profit association dedicated to the development and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand globally and across multiple sectors*" (GS1, 2012).

4.6 Merits of tracking, tracing and visibility

Tracking and tracing is critical in the current business environment either in response to legal or compulsory requirements or as voluntarily initiatives to improve internal and external business processes. Recently, different business sectors such as healthcare, retail, constructions, logistics, food, pharmaceutical, automotive and aerospace; have shown greater interest in improving traceability and visibility of assets driven by the advancement in tracking technology. Efficient tracking and tracing practices are able to ensure important business aspects including ethics, authenticity, quality, safety security and sustainability. The discussion of each of these aspects is now presented in turn and illustrative case studies are provided when it is appropriate.

4.6.1 Ethics and authenticity

There is a growing awareness among consumers themselves and consumer protection agencies to ensure ethics and authenticity of products. Ethical business issues may be related to ethical labour practices (e.g. avoiding child labour, and sweatshop labour); food with special requirements due to ethnic/religious background or beliefs or special dietary or premises (e.g. kosher, halal, vegetarians, vegan, eco-friendly or organic food); and companies' social responsibility (e.g. the use of recyclable packaging, fair-trade products, donations to charities/society, eco-friendly components and material) (New, 2010).

Authentication of products is related to ensure the original make of products rather than the copy ones. In some situations, it is very difficult even for companies to differentiate their real products from the fake ones unless they carry out chemical tests (GS1, 2012; New, 2010). Track and trace products' information can help in preventing or eliminating counterfeiting through the ability to differentiate between fake and original products such as designer/copy clothes, watches, fragrance, and handbags, original/counterfeited medical products, organic/non-organic food products, leather/artificial leather items, free range/battery eggs.

Product labels may provide a range of traceability information about products e.g. brand, contents/compositions, usage instructions, where it is made, conformance to ethical premises, quality and environmental standards, and even product logistics and inventory information (New, 2010). In most cases, the more product information you can track and trace, the more innovative tracking technologies are involved.

The study provides an illustrative example to show how tracking, traceability, and visibility may enhance authenticity (GS1 UK, 2012b).

Food authenticity: Feile Foods (summarised version from original example - source: (GS1 UK, 2012b)

The company: Fiele Foods
Feile Foods, an Irish meat processor and retailer, operates a fully licensed meat processing operation in Portlaoise, Ireland. It processes beef, lamb and pork products which are sold in its own retail outlets as well as to retailers, wholesalers, caterers and hospitality customers. With a proactive approach to technology, the company has invested in a computerised production management system for its processing facility and integrated POS systems for its outlets.

Challenge: improve product authentication and traceability of fresh produce.
As a substantial part of the business involves producing products to be sold in retail outlets, Feile was looking to automate as much of its supply chain as possible and identified bar code scanning solutions as a way to eliminate manual data entry processes and errors.

Solution:
Feile Foods is using the GS1 DataBar Expanded Stacked symbol that is optimised for omni-directional scanning at the POS. GS1 DataBar is a new bar code that can deliver enhanced product identification at retail POS. Its ability to store additional information such as price, weights and expiry dates can support new POS applications such as improved product authentication, traceability and product recalls.
The Bar code system used by Feile contains the following product information:
- *GTIN (Global Trade Item Number), the GS1 standard used to identify products*
- *Batch number*
- *Price (for variable weight products)*
- *Weight (for variable weight products)*
- *Expiry date*

Benefits:
- ➢ *The combination of a GTIN and batch number enables the system to check automatically if an item has been recalled and prevent accidental sale*
- ➢ *A more detailed view of real-time inventory is enabled with additional information such as batch codes and expiry dates as well as the GTIN*
- ➢ *The new bar code system contains both the price and weight of each item which can be recorded at point-of-sale*
- ➢ *The expiry date can also be checked and recorded at the POS and printed on the customer receipt*
- ➢ *The batch number is recorded at the POS and printed on the receipt so customers have a copy if they lose the packaging*
- ➢ *Batch numbers recorded at the POS can be matched with customers through loyalty card schemes, enabling a recall even after the sale is completed*
- ➢ *Regulatory responsibilities are easily achieved with a data rich track-and-trace system*

4.6.2 Quality

Tracking and tracing can be used to ensure that the quality of an object is maintained at all times. Quality of an object is assessed through the extent to which physical and functional status meets the approved quality standards. Quality is an influential indicator for reliability i.e. the object ability to do its job efficiently. Quality needs to be monitored from raw material until reaching the consumers' hands. This entails tracking and tracing practices within manufacturing facilities and across supply chain operations.

In manufacturing, quality control is managed based on establishing continuous monitoring and traceability procedures as a proactive approach to eliminate and/or prevent any source of errors and defects which are the essence of just-in-time systems and lean operations. A recent study has found that utilisation of RFID as an innovative tracking system results in enhanced efficiency of manufacturing that lead to enhanced organisational performance and effectiveness of manufacturing that positively affects supply chain performance (Zelbst, Green, Sower, & Reyes, 2012). Shelf-stock tracking is a routine daily process in supermarkets and retail stores to check the validity and physical condition of products especially perishable ones. With regard to supply chain logistics activities, products such as blood; hazardous and some chemical substances; drugs, perishables, dairy and frozen products require maintaining specific environmental or atmospheric conditions e.g. high/low temperature, humidity, air pressure or light specifically during their journeys across SC. Here, tracking and tracing are crucial to monitor the quality level and to ensure products' reliability.

The study provides an illustrative example to depict how tracking, traceability, and visibility may enhance quality (Association for Automatic Identification and Mobility (AIM), 2007).

Manufacturing quality and efficiency: Vicaima Door Designer (summarised version of original example – source: (Association for Automatic Identification and Mobility (AIM), 2007)

The company: Vicaima

Vicaima is using RFID to slam the door on inefficiency. The company faced a growing worldwide demand for its elegant, stylish wooden doors. Vicaima was expanding from its traditional base of operations in Spain, Portugal and the United Kingdom, and to meet the growing customer demand, the company turned to an EPC-compliant RFID installation to carve out efficiencies in its production and stock control systems.

Challenge

Vicaima views doors as works of art, bringing harmony and privacy into people's lives. And behind that philosophy is a focus on continuous improvement. To reduce manpower time and increase efficiency in its manufacturing processes, Vicaima was the first in the door/window production industry to roll out an EPC-compliant RFID installation. "We constantly seek technologies to help maximize the quality of our products and services," says Filipe Maia Ferreira, managing director of Vicaima. "Alien's RFID solution, using the Squiggle tag affixed to each door, greatly reduced the amount of human intervention required for process controls while virtually eliminating tracking errors – resulting in greater flexibility and efficiencies at the production control level."

Solution

Vicaima has deployed its RFID application in production at two factories, one that specializes in mass production wooden doors and another that specializes in special order doors, and the deployment will encompass millions of tags. Tags are coded, printed and attached on the production line. Products can be located quickly and accurately, facilitating movement throughout the production process and to the warehouses and trucks.

Tags are instrumental in stock-taking processes, so Vicaima always has an accurate inventory. The RFID application is integrated with Vicaima's ERP system for maximum flexibility and efficiency at production and stock control levels. Once the tags are attached to the door, the door is tracked throughout the production process. The system is fully automated, so the machines can read which door is arriving and know what process should take place. It's also clear where the door needs to go next, whether that's another station on the production line or to the warehouse. Workers save time because they do not have to register the doors in the ERP system, since the products are automatically validated.

Benefits:

- *Reduce human intervention required for manufacturing process controls*
- *Eliminate tracking errors*
- *Greater flexibility and efficiencies at production control level*

4.6.3 Security

Human identification is an important aspect of tracking and tracing practices driven mainly for security purposes and is used widely by various organisations and public security agencies. It is also significant in tracking livestock, athletes, children in open areas, pets and soldiers. With respect to business applications, tracking and tracing is essential for products' security that can be related to the nature of products e.g. hazardous, fragile, sensitive and/or valuable. Appendix F (p.395) illustrates the research findings of the key characteristics of products that may influence the extent to which security aspects need to be maintained across a supply chain. For example, high value products are subject to theft and looting. Most retail stores especially, those deal with designer clothes and high value items, use automatic tracking system to stop shoppers stealing their products. Product security across SC logistics operations requires more sophisticated tracking and tracing practices compared to in-door ones especially, when considering the features of contemporary transport logistics environment that are presented later in the following section.

The study introduces an illustrative example that illuminates how tracking system may help in maintaining security of products (CoreRFID, 2009).

Security and service management: Quantum Saddles (summarised version from original example – source: (CoreRFID, 2009)

The company: Quantum Saddles
Techniques of saddle manufacturing haven't changed for over two hundred years but Quantum has taken a new approach using new techniques and new materials for their custom saddles. At the heart of the Quantum saddle is a high-tech design based on the use of carbon fibre to provide a light weight, stable and secure base for a saddle that is custom fitted to both horse and rider.

Challenge
Quantum saddles are designed for heavy use in the demanding sports of show jumping, dressage riding and endurance. Even with the Quantum's rugged design repairs are occasionally necessary and Quantum provides a warranty and repair service for their customers. However, the tailored nature of the saddle means that individual components for one customer's specific saddle need to be kept together.

The challenge with servicing a highly customised product is the need to ensure that the specific item is identified in the service process and that the original item or one directly matching it, is returned to the customer after servicing. This depends on the ability to recognised a specific, unique individual product. Quantum places a strong emphasis on customer service. Its customers are often leaders in their chosen sport. Their quest for performance excellence means they demand excellence in their equipment suppliers. For Quantum this created the need for a service operation that was a tailored to the customer as the saddle is.

Solution
In the case of Quantum, the service areas involve the three main components of the saddle; the seat and the two saddle flaps each of which has its own, tailored, carbon fibre fin. Using RFID tags each component piece can be identified and linked to an individual customer. This ensures that after service or repair the parts of the saddle can be correctly reunited, within the service operation before returning them to the customer. In addition, RFID tags provide security by monitoring saddle components for authenticity.

Benefits:
Quantum Saddle's RFID based warranty & service management approach provides:
- *Automatic, accurate identification of items for service.*
- *Reliable linking of components for return after service.*
- *Security / authenticity checking of saddle components to prevent tampering*
- *Easy access to accurate customer information for saddle fitters.*

4.6.4 Safety

As previously mentioned, track and traceability practices are essential to ensure consumers' safety by ensuring safe products e.g. food, automobiles, aircrafts, medical devices and products and toys.

In the healthcare sector, patients might lose their life or be disabled due to the wrong treatment or medication error. "*The Institute of Medicine estimates that more than 44,000 Americans die each year in hospitals from medical errors, with 7,000 resulting from medication-related errors alone*" (Association of Automatic Identification and Mobility (AIM), 2008). Good tracking and tracing practices can improve patient safety through the ability to track medication (i.e. the right dose at the right time), track patients (i.e. the right treatment to the right patient), stop medication counterfeiting (i.e. authentic drugs rather than counterfeited one) and reduce data errors (GS1 UK, 2012a).

In the food industry, tracking and tracing practices allow information visibility about where the food comes from, when it is produced and for how long it is valid, its compositions, its usage, storage and safety instructions and its route from first supplier to consumer, etc. With respect to transport service such as airline companies, traceability is a significant mechanism for predictive and preventive maintenance practices through which passengers' safety is ensured.

Tracking and tracing are also important and a legal requirement to ensure safety of workplace environment. For instance, in mining, chemical, cement, pharmaceutical, iron and steel industries, the conditions of the workplace environment (e.g. air pollution, light and noise) must be monitored not to exceed accepted limits. Besides, human tracking is significant in some sectors for safety reasons especially, in offsite-based operations such as mining, fishing, hunting, search and rescue service and cutting trees in forests.

The study presents an illustrative example to show how tracking, traceability, and visibility may enhance safety (Association of Automatic Identification and Mobility (AIM), 2008).

Patients' safety: St. Clair Hospital (summarised version from original example – source: (Association of Automatic Identification and Mobility (AIM), 2008)

The organisation: St. Clair Hospital

St. Clair Hospital of Pittsburgh, a 331-bed independent community hospital, founded in 1954.

The challenge: prevent medication errors at a patient's bedside
When nurses give pills, intravenous fluids or other medications to patients, there are many risks involved, such as providing the wrong type of medication, the incorrect dosage or administering it at the improper time.

Solution
St. Clair Hospital is proactively reducing medication errors with its innovative Five Rights Medication Verification System, which enables nurses to confirm in real time, right from a patient's bedside, that they are correctly administering medications to patients. The Five Rights Medication Verification System checks five conditions whenever a medication is administered. Specifically, it aims to ensure that the right patient receives the right medication and the right dose at the right time, using the right form of administration.

Before administering medication, nurses first read the RFID tag in their badge to log in. They then scan the bar code on the medication package and the RFID tag in a patient" wristband. The data is sent wirelessly from the SoMo 650 over the hospital's Wi-Fi network to the main clinical database, where the information is compared with the doctor's latest orders.

Voice commands on the SoMo 650 immediately announce "Patient identification confirmed" or in the case of discrepancies, "Access denied." Information is also presented on-screen, including a photo of the correct patient, which was taken during the patient's admission to the hospital. Since the SoMo 650 is connected to the hospital's wireless network, nurses know immediately about any new medication orders, order changes or cancellations.

Benefits
The system has enabled the hospital to identify and prevent 5,000 potential medication errors each year. Besides saving lives of patients, it also saves time for nurses, so they can give more attention to patients in their care.

4.6.5 Sustainability

Sustainability is of interest considering environmental regulations and consumer perspectives. Recently, sustainability has become an influential business strategy through which business value can be created. To ensure companies conform to environmental standards and legislation, tracking and traceability is an essential tool to monitor the environmental performance of companies i.e. monitoring the level of air pollutants transmission, liquid and solid waste disposal. As such, product traceability information helps consumers and investors to make their buying and investing decisions.

With respect to supply chains, transportation is the highest growing energy consumer in Europe with an increase 47% since 1985 whilst other sectors have increased by 4.3% (Mason & Lalwani, 2006). The contemporary features of transport logistics activities illustrated in the next section increase the significance of tracking and tracing practices in diminishing energy consumptions and pollution.

4.7 Merits of RTAs tracking, tracing and visibility

To draw on the merits associated with RTA tracking, tracing and visibility, it is useful to start with providing a snapshot of the contemporary business environment influencing transport logistics operations.

4.7.1 Business environment and transport logistics

Here are the key factors influencing transport logistics operations across global supply chains.

- Global competition has led to relocating factories and distribution centres aiming at attaining cost efficiency and a competitive advantage (Lai, 2003; Stock, Greis, & Kasarda, 2000);
- 90% of global trade has been containerised with 10% annual growth (Ennovasys, 2011a);
- Streamlining international and domestic trade at the same time preventing the entry of illegal products to maintain safe borders;
- Lead-time pressure of both time-to-market and order-to-delivery forced companies to be faster in terms of time to their customers;
- The advancement in ICT has changed the way of managing supply chains to be driven by demand side (order from point of sale);
- Due to changes in national and international trading rules and regulations, demand for freight transport has changed with more focus on hub and spoke network, cross docking and merge-in-transit systems (Lemoine, 2004);
- Increasing trend towards outsourcing of logistics activities using third party logistics (Lemoine, 2004);
- Reducing the number of suppliers with more robust relationships;
- Reconfiguring the European supply chains to be leaner in terms of the number of distribution facilities (O'Laughlin et al., 1993).

RTA, as the basic physical units across supply chain logistics operations are directly related to the aforementioned factors. Improvement in the management of these assets has a direct impact on transport logistics activities i.e. shipping, transportations, receiving and internal firm operations. The evolution of advanced tracking technologies enable automatic track and trace at loading/unloading points, entry/exit gates, throughout the distribution centres, factories, warehouses, ports and receiving docks at wholesale or retail places. It also enables automatic tracking over transport journey of shipments. Managing RTAs entails incorporating both tracking and traceability information that needs to be communicated to ensure visibility.

4.7.2 Merits *of RTAs tracking, tracing and visibility*

A number of advantages are associated with enhanced tracking and traceability of RTAs as follows.

- Visibility of RTAs may lead to reductions in the size and configuration of RTAs' fleet that in turn reduce the rental cost and deposits or reduce the investment in RTAs' fleet (Angeles, 2005; Johansson & Hellström, 2007);
- Angeles, (2005) argues that visibility of RTAs reduces the charges that the firms incur because of RTAs detention for the 3PL by 80 percent;
- Reducing transport costs by decreasing the rate of emergency transport, error of shipments, late delivery, empty running problems, and loading and unloading process (Aberdeen-Group, 2004; Brewer, Sloan, & Landers, 1999);
- Efficient use of field engineers time and budgets;
- Reducing the cost of maintenance and repair of RTAs and expansion the usage life of the asset (Aberdeen-Group, 2004; McFarlane & Sheffi, 2003);
- Reducing the cost of replacement through minimising the rate of shrinkage due to loss and thefts and counterfeiting (Aberdeen-Group, 2004);
- Reducing handling and warehousing costs by minimising warehouse space and through automatic handling and sorting (Michael & McCathie, 2005).
- Resources utilisation, including waste, time and error reduction can be improved incorporating the following factors:
    - Waste reduction can be in the form of reducing buffer stock/stockpiles and emergency orders due to stock-outs and/or misplaced items;

- Time reduction is related to minimising the time required looking for assets and the time spent processing shipments;
- Error reduction is about eliminating errors associated with picking wrong assets causing shipping errors and incorrect orders that ends with dissatisfied customers (Kelepouris, Baynham, & McFarlane, 2006a).

- Resource utilisation results in better return on investment in assets through expanding their usage life.
- Better maintenance management practices that enhance reliability of assets;
- Enhanced customer satisfaction through better customer services (GS1UK, 2011).
- More regulations are expected to guarantee security and safety along supply chains, specifically, those related to RTAs (Marcel, Veenstra, Meijer, Popal, & van den Berg, 2007). In 2011, new rules have been issued in the US to stop theft of plastic pallets that are usually left unattended at the back of stores through tracking thieves who steal these pallets. Any recycling company buying more than five pallets with a company logo at one time, are expected to get identification from seller and record these identification details (Reusable Packaging Association (RPA), 2011).

4.7.3 Asset tracking: an illustrative case study

The following illustrative example provides an example highlights the potential merits of asset tracking systems at an RTA level (Association of Automatic Identification and Mobility (AIM), 2009)

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Asset tracking: Southeastern Container (summarised version from original example- source *(Association of Automatic Identification and Mobility (AIM), 2009)*

The company: Southeastern Container
Southeastern Container was formed in 1982 as a privately owned company under the ownership of a group of Coca-Cola® Bottling companies. Today the company operates as a manufacturing co-op with ten manufacturing locations producing plastic bottles. Southeastern Container handles nearly 70 percent of the bottle production for Coca-Cola in the U.S. and also works with bottle manufacturers outside of the co-op. The company keeps quality and service high with a focus on continuous improvement.

The challenge: Inventory control and traceability for specialized product containers
With roots in the southeastern U.S., Southeastern Container now has ten manufacturing facilities across the East Coast, Illinois and Wisconsin. At the company's three injection molding facilities, bottle blanks called preforms are manufactured. The plastic preforms are blown into bottles at Southeastern Container's blow-molding facilities and at bottle manufacturers outside of the co-op.
The preforms are shipped to bottle manufacturing plants in cardboard containers or existing plastic bins. Ideally, these containers are returned empty to the injection molding facilities to repeat the cycle. However, problems with this return process were costing Southeastern Container thousands of dollars each year.

Some containers are lost or damaged in transit and must be replaced. In addition, the design of the existing containers prohibits Southeastern Container from maximizing the capacity of shipping trailers, resulting in the company paying to ship "air" for each load. Finally, cardboard containers are often pre-assembled to save time, and the fully assembled containers take up warehouse floor space. In the process of shipping billions of preforms, these issues add up.
Southeastern Container planned to address these problems by replacing the existing containers with a new version— a specialized returnable plastic bin. While the new folding bins are designed to significantly reduce costs and increase efficiency, each of them is nearly ten times the cost of a cardboard container. Thus, cycle counting would be introduced to track bin lifetimes against the number of cycles guaranteed by the manufacturer.

Applications
Cycle counting and RFID tracking of reusable product bins with capabilities for expanded warehouse control and inventory management in the future

Benefits
Saving thousands of dollars a year in transportation costs, reducing container loss and ensuring traceability, achieving ROI within two years of full implementation, providing accurate data on bin lifetimes for warranty contracts, and establishing a successful use-case with RFID technology to leverage with a wide range of future warehouse and inventory control efforts

4.8 Types of tracking systems

Types of tracking and tracing systems can be classified in terms of low-tech systems that are usually associated with low cost and high-tech ones that in most cases coincide with high cost. In this research, four groups of low-tech tracking systems are introduced including manual identification, visual management, rewarding approach, and outsourcing. On the other hand, three key types of high-tech tracking systems are presented incorporating automatic identification (Auto-Id), location and automatic visual tracking technologies. The low- and high-tech applications are not mutually exclusive. The following section starts with low-tech/cost tracking applications and moves into will be followed by the high-tech/cost applications.

4.8.1 Low-tech/cost tracking systems

4.8.1.1 Manual identification systems

The interest in identification of materials coincided with the introduction of material management concept in 1950s that includes " *all the control flow and physical goods flow activities in a firm up to and often through the production process*" (Cavinato, 1984). Materials, might incorporate stock in trade, raw materials, piece parts, bought parts, equipment and spares, tools, gauges, jigs and fixtures, work in progress, packaging materials, scrap and residues and other general materials that do not fall within any other categories (Jessop & Morrison, 1994, pp.22-23). Up until 1970, traditional manual identification or coding systems were the prevailing tracking pattern. This form of tracking system is mainly based on human readable alphabetical (e.g. GFCA), numerical (e.g. 88/34/1582), or alphanumerical (e.g. DF1582) text. The item code is manually painted, written, fixed on or attached to an object (Bollen et al., 2004; Cavinato, 1984, p.333). In addition, colour marking can supplement or in some cases replace (e.g. with small components or parts) the identification code adding a visual tracking dimension.

There are different types of codes and most of them are designed to meet the business requirements that might be related to the function of items, their nature, their source of supply or their location (Jessop & Morrison, 1994). Once the coding process is accomplished, the lists of code numbers, descriptions, size, etc. are created in a document called vocabulary (Jessop & Morrison, 1994).

Identifying an object manually entails eye tracking and manual reading of full or abbreviated descriptions that might not be easy and could be confusing (Jessop & Morrison, 1994). As key limitations, these systems involve immense labour work resulting in high labour cost, inaccuracy, inefficiency, poor quality, errors, delays, etc. Manual identification systems are now rarely used at a final product level as have been replaced by barcodes systems that were introduced in the 1970s and developed significantly in the 1980s (Coyle, Bardi, & Langley, 1992).

Manual identification systems facilitate tracking i.e. identifying the current state of an object, but are limited in their abilities to achieve traceability i.e. identifying the past state of an object. These systems can be still seen in some business areas such as small-sized warehouses and stores (e.g. manual identification of products); equipment and facilities management (e.g. manual identification of computers and furniture) in some organisations such as factories, universities, schools, and hotels; and logistics service (e.g. manual identification of RTAs).

4.8.1.2 Visual management approach

Visual management is a lean concept that uses visual cues to prompt human behaviour to take logical action (Parry & Turner, 2006). The mechanism of visual management is visual communication that is clearer and quicker than written or oral instructions influenced by discrepancies in culture and language. Visual clues can be used in all activities to monitor if the process is performing, as it should be.

Visual management as a management approach seeks to enhance mainly the firm's internal operations. This approach allows individuals who are involved in a business process to visually track and assimilate various aspects of the processes for performance without the need to record and analyse lots of data (Parry & Turner, 2006). Transparency of physical and information flows allow instant feedback and identification of where adjustments need to be made to streamline operations (Womack & Jones, 1996). This approach is triggered by the ideas of lean and JIT systems focusing on eliminating unnecessary non-value adding activities that can be translated in terms of waste including inappropriate processing, overproduction, unnecessary inventory, unnecessary motion, defects, waiting and transport (Hines & Rich, 1997).

Visual management approaches are based on tools and techniques that can be simple, yet efficient that might include symbols, pictures, posters, graphical representation, colour coding and transparencies (Parry & Turner, 2006). This approach can be alternative, pre-requisite or a complementary tool to high technology. A visual management approach fits well for companies that are not able to invest in IT applications. In considering small firms, it is argued that smaller warehousing using lower automation levels tend to be more efficient than larger warehouses (Hackman, Frazelle, Griffin, Griffin, & Vlasta, 2001).

Visual management can enhance visibility specifically at an operational level and can generate a number of advantages including: eliminating and/or preventing waste, improved quality based on error reduction and/or prevention, improved efficiency through an organised workplace, enhanced safety and security aspects and thus minimised total costs (Breyfogle, 2007).

The key tools of a visual management approach are those associated with lean and JIT operations including visual stream mapping, visual workplace, visual information, visual control, visual performance measurement, and visual safety and security control. This section draws on various types of visual management techniques.

a. Value stream mapping (VSM)

Value stream mapping is a technique through which a company develops a one page map or picture of all the operations and processes included from the time of placing an order and the time of delivering the product to a customer (Magnier, 2003). Rother and shook, (2003) define VSM as "*a pencil and paper tool that helps you to see and understand the flow of material and information as a product makes its way through the value stream*".

The key objective of this technique is to portray the physical flows of material and the information flows throughout all value-adding activities carried out to produce and deliver products to customers as a simple tool of communication used by individuals. VSM is based on the idea of improving the internal flow of operations rather than enhancing processes in isolation. The role of value stream mapping is to create a snapshot of current practices illustrating value-adding, necessary non-value adding and un-necessary non-value adding activities so that, sources of waste can be identified (Hines & Rich, 1997). Improvements need to be made especially those related to un-necessary non-value adding activities. Therefore, improved value stream mapping is employed as future or ideal operational road map.

Rother and shook (2003) indicate four main steps to VSM including (1) to define and to pick the targeted product or product family (e.g. products sharing similar or common main or optional processes); (2) to develop the current state VSM; (3) to create the future state VSM; (4) to develop an implementation plan to replace the current state VSM by the future state VSM.

Developing a VSM requires defining its scope, selecting symbols, icons and data, brainstorming the preliminary map, identifying missing information the VSM needs, gathering and developing information about sources of waste, creating the current state VSM and developing a list of potential improvements (Magnier, 2003). The transition from the current state VSM to the improved one requires the involvement of all stakeholders, regular meeting of all participants and a structural approach for problem solving and for tasks accomplishment (Rother & shook, 2003).

Non-value adding activities such as waiting, unnecessary motion, inappropriate processing and unneeded inventory constrain proper track and trace practices. VSM provides a useful visual tool that can improve the flow of processes and information that in turn can optimise track and trace practices at a shop floor level.

b. Visual workplace (5S workplace organisation)

5S is a lean approach for workplace organisation that was developed as part of Toyota production system. It is "*a five-step technique for changing the mindsets of the staff and involving the entire organisation in improvements*" (Sarkar, 2006). 5S is seen as the basis or the starting point for other process improvement initiatives. According to 5S approach, a workplace such as a manufacturing plant and offices should be clean, orderly and organised that allow a smooth flow of operations and processes. Therefore, housekeeping in terms of continuous cleaning and tidiness is important part of 5S philosophy through which the waste in a workplace can be eliminated (Sarkar, 2006).

The key benefits of 5S is to have an organised workplace; develop a sense of belonging among individuals and teams; enhance the productivity and efficiency of employees; minimising turnaround time to do tasks and jobs; eliminate waste, force ownership of every work area, item and equipment; remove items that are not needed in a workplace, clear lots of valuable areas; enhance team interaction and team spirits and create a quality and problem prevention culture (Sarkar, 2006).

Establishing 5S is a long and difficult process because it requires changing every day habits of individuals and teams in different areas of a workplace (Anonymous, 2006). The five steps of 5S implementation that cover all the areas in a workplace includes:

sort (Seiri), set-in-order (Seiton), systematic clean (Seisu), standardise (seiketsu) and sustain (Shitsuke) (Anonymous, 2006). Here is an overview about each stage.

- ***Sort.*** The first stage when conducting 5S approach is “Sort” which is about getting rid or eliminating anything that is unnecessary or is not being used for accomplishing the job. Taking live snapshots of the workplace using photos makes it easier to see 5S problems than just walking past them during the workday (Anonymous, 2006). Anything can be removed without influencing the smooth flow of process is considered waste. Different types of waste are considered such as damaged equipment, old tools, broken items and obsolete procedures. In addition, items that are not in use for a month long should be removed.
- ***Set-in-order.*** The second stage of implementing 5S is to find a right place for everything, to put everything in its right place and to make sure nothing in a wrong place (Sarkar, 2006). The most frequently used items need to be near to those who use them. In set-in-order stage, there are many questions need answer e.g. where to keep stuff, how many stuff are required and how to replace them on time.
- ***Systematic clean.*** As the third stage of 5S, systematic clean is a proactive approach that comes in line with total productive maintenance perspective. The essence of systematic clean is to maintain a good working condition of the workplace e.g. manufacturing plants, warehouses or offices that includes equipment and various tools. The staff or the teamwork takes the responsibility of systematic clean.
- ***Standardise.*** This stage is about establishing the standards and making them formal. The standards are developed during the first three stages. They include templates, new procedures, instructions and photos that enhance learning process and prevent going back to the old disorganised workplace (Anonymous, 2006). If possible, the standards need to be visual especially a reminder of the procedures that is usually called “one point lesson” (Anonymous, 2006).
- ***Sustain.*** The fifth stage of implementing 5S is about maintaining and continuously improving the standards to eliminate waste. This entails checking against the standards and using the outcome to improve current standards. Sustainability of 5S philosophy ensures visual workplace as the basis for further operational improvements.

5S is a powerful approach in facilitating tracking practices that uses visual tools e.g. notices with instructions; signs for directions and places; shelf, rack and RTAs labelling; pictures of objects to be stored on a shelf; tool shadow boards and tool tracer to visibly store objects frequently used; coloured-coded smocks to determine specific capabilities of associates, u-cell manufacturing assembly, and marked floor and wall to guide directions of the process flow (Anonymous, 2007; Neese, 2007; Tezel, Koskela, & Tzortzopoulos, 2009).

c. Visual information

In many firms, knowledge is still a sign of authority, so that individuals try not to share it. Sharing information is the trigger for effective and efficient decision making process at different levels. Visual documentation is an important aspect to change the idea about propriety of information as a source of power (Greif, 1991). In addition, training and skill boards are another visual information tool.

Process documentation

Documentation is seen as the act of recording the steps of a process in a consistent format. Consistency in the company's output facilitates improved productivity and information sharing activities that encourages teamwork, and it also eases cross-training and job rotation (Anonymous, 2012c). Process documentation is defined as *"a method of concisely capturing and sharing critical project concepts, plans and information as they are developed, so that impacted parties can share this information, make informed decisions, and keep the project moving forward without having to revisit old discussions*" (Joseph, 2012). Accurate process documentation is a basis for internal controls testing, risk analysis and process improvement (Joseph, 2012).

The common method used for process documentation is to create an end-to-end process flow. Process flowcharts and checklists are considered two of the most popular format that can be created manually or electronically. Pictures are much better than written documents; however, they take longer to develop. The time needed to document a firm's processes is conditioned by the frequency of use, the need for clarity, and the importance of the process. One picture is equal 1000 words (Anonymous, 2012c). Process flowcharts could be useless if they are not used or can't be found (Joseph, 2012).

There are useful sources when documenting a process incorporate the use of historical records, current document, case studies, field diaries of project staff, video and audio recording, structured interviews, participant observation of users, newspaper clippings, software development, and reconstruction of events (Joseph, 2012).

Some organisations follow formal technique for recording their processes while in other companies, it is more ad hoc or for internal purposes. Process documentation can be a requirement of a third-party e.g. for ISO certification. Process documentation using flowcharts as a visual information technique is useful in tracking and monitoring the flow of business processes in various areas.

Skills and training boards

The key purpose of skills and training boards is to track the requirements of competence development among the team and to ensure the right number of employees with the right skills doing the right job (Anonymous, 2007; Neese, 2007). Flexibility in using the staff is a requirement in modern production systems that entails cross-training of personals. Skills and training board shows who is trained in which disciplines within certain area. Team boards show the details of everyone and their responsibilities in each area. In addition, colour coded jackets/shirts/caps are used to recognise worker types within the each area. As part of the aforementioned visual workplace using 5S, storyboards are used to track the progress the teams make as a way of celebrating and highlighting team working (Anonymous, 2012d).

d. Visual control

Visual control incorporates the implementation of different tools such as production control boards, kanban visual signals and e-kanban, scheduling boards, Andon boards and lights, Gemba walk and visual process indicators. This section illustrates these tools.

Production control boards

Production control boards display the day-to-day operations' story. They also could trace historical operational information to indicate the monthly or weekly operational trends (Davis, July 2010). Production control boards should be updated frequently (often hourly) by operations' staff showing the current state of the operations. There is no standard layout of the production control boards; flowcharts and coloured pictures can be used (Anonymous, 2012a). Different colours can be used that have different indications and in turn different actions. Thus, production control boards facilitate visual communication as everyone at a glance whether being familiar with the operations or not can understand the operational situation.

The supervisors can make decisions on the floor if any operational adjustments needed that save their time and effort. Production control boards eliminate the misinterpretation of and the argument about production data especially when discussed in closed offices through minimising the variation between statistics and reports, and actual reality (Anonymous, 2012a). Using production control boards encourages more engagement of the team members in the process as they are aware more of the everyday progress they made toward goals (Davis, July 2010).

Kanban visual signals

Kanban is a visual control technique used by Toyota and it is one of the key pillars for its success in JIT systems. Kanban can be seen as a demand scheduling that replaces traditional daily or weekly schedule with visual signals and predefined decision instructions that facilitates scheduling the production line (Zhang, 2010). The key benefits of Kanabn system at shop floor level include eliminating waste based on first in first served of materials and product at individual operations; transparency of process and transparency of bottlenecks (Parry & Turner, 2006). The most common type of physical signalling for the Kanban is *Kanban cards*, yet there are other types incorporating Kanban boards, look-see Kanaban and two-card Kanban. The research draws, in turn on each of these types.

Kanban cards as a transaction and communication device are basically "*pieces of paper which travel with the production item and identify the part number and amount in the container*" (Zhang, 2010). It is often used in assembly lines.

Kanban boards works differently as it uses for example, plastic chips, magnets and coloured washers. Kanban boards help to eliminate work in process, visualise the workflow and measure the lead-time. Here, the objects are backlog products and in-process inventory items. There is no standard way to design Kanban board, each company can create its own pattern (mainly the number of columns) according to its operational condition (Zhang, 2010).

Look-see is "a Kanban signal that behaviours relying on the sensor of people's eyes" (Zhang, 2010). It implies the use of visual signals e.g. using floor marking to illustrate the time to replenish the object. The colour of the signal indicates specific action. Yellow is a scheduling signal that means replenishment of the object is due to now. Green signal indicates no action need to be taken whilst; red signal indicates an immediate action is required. In some cases, containers can be used as look-see signal for controlling physical flows.

Two-card kanban is a mixed system of Kanban card racks and Kanban board. It is mainly used for bulky items that do not allow the utilisation of flow racks. Two-card Kanban allows the flow of pallet size objects while managing the rotation of products. It is quite appropriate for floor stacked objects.

E-kanban

Toyota has developed a new kanban system called electronic Kanban (e-kanban) to overcome the problems associated with paper-based kanban (Wan & Chen, 2008). E-kanban is "*a parts ordering information system that operates within the communication network established between Toyota and its suppliers"* (Kotani, 2007). Paper-based kanban seeks manufacturing efficiency yet, capacity requirement, variety of products, demand fluctuation and/or long distance between facilities make kanban system too complicated (Wan & Chen, 2008). IT applications especially ICT are valuable tools to enhance the visibility of kanban system and minimising related barriers. The logic behind e-kanban system is the integration with ERP and EDI applications along with web-based technology (Drickhamer, 2005). E-kanban is an efficient tool for accurately changing the kanbans number once the wanted number has been computed as this influences the quantity of the order. Thus, the status and location of kanbans within the supply chain can be visible through virtual access to the system. E-kanban can diminish human errors associated with paper-based kanban and enable monitoring, tracking and performance measurement (Wan & Chen, 2008).

Scheduling boards

Scheduling boards display the schedule requirements and attainment within the workplace. This shows if the company is up to speed to meet the schedule requirements. Scheduling boards are simple, understandable and lees complicated than electronic printouts (Anonymous, 2012d).

Andon boards and lights

Andon boards and lights were first employed by Toyota production system to illustrate abnormal operational conditions. They support the principle of autonomation or Jidoka (one of Toyota Production System techniques through which a machine stops automatically if there is an error, defect or other problems) through highlighting the status of a process or a machine to attract attention (Anonymous, 2007).

Andon boards are a visual control tool that attract attention to the status of operations and emerging problems (Parry & Turner, 2006). Andon could be individual lights attached to each machine or a group of lights on a main board hanged on the plant floor showing the state of an operational cell/area. When there is an operational problem e.g. reject materials, delay, or breakdown, the operator pulls the andon (sometimes called line-stop) cord that trigger lighting or blinking (Anonymous, 2012d; Krisby, 2009). This alerts the line supervisor to help the operator to finish the operation on time, to figure out the causes of the delay and to stop the consequence defects or problems in the subsequent processes (Krisby, 2009). Coloured light may indicate different things; for example, a red light may refers to a line stoppage whilst a yellow light may be a sign for a potential slow-down (McCaghren, 2005). Different actions need to be taken in each case.

Gemba walk

Gemnba walk is a low cost visual management approach through which leadership and managers leave their offices and get into the workplace. This simple technique keeps the managers in touch and informed about everything going on in the workplace. Gemba walk helps manager to self-track day-to-day operational problems and to effectively manage the people who are involved in solving these problems (Anonymous, 2012b). Managers, engineers and supervisors can do a Gemba walk once a day or several times during the day. Gemba walk helps managers to develop good relationships with their staff and to break barriers with them through face-to-face communications (Anonymous, 2012b).

Visual process indicators

Various visual measurements can be used to control jobs in progress, productivity, output and lead-time. For example, visual tools help to control maximum levels of work-in-progress to avoid overproduction and buffer stock (Anonymous, 2007). Toyota

Production System use physical storage bins as a mean to manage work-in-progress and to control the physical flow of production (McCaghren, 2005). The logic behind the use of physical storage bins as physical displays is that if the sized storage bin is full, it is a visual sign to upstream operations to stop the production. In addition, visual tools can be used to control the daily output, productivity and lead-time. The aforementioned andon board can be implemented to display the daily operational goals, the current daily output, the downtimes of the system and the deviation from the goal (McCaghren, 2005). Effective andon boards should allow visibility from each area in the floor, instant process information, flexibility to adjust to changes in a process, and clearly interpretable data (McCaghren, 2005).

Visual performance measurement

Visual performance measurement in modern production systems is about developing key performance indicators (KPIs) for each process and work team that focuses on driving firm’s competitive advantage and eliminating various types of waste (Taylor, 2011). KPIs simply represent a tool that facilitates evaluation and improvement of various business aspects using customised and non-customised measures within a firm through which the level of success or failure of each area can be indicated (Anonymous, 2010b). Visual performance indicators should allow visual and short cycle feedback. The most common visual tools to display KPIs incorporate dashboards and quality charts.

Dashboard metrics relying on KPIs

Dashboard is often a screen that displays various performance information of a business in the form of graphs, summary of reports and scorecards (usually in the form of table of figures). Effective dashboard metrics should display well-defined, interpretable and understandable data. The representation of data should consider consistency in terms of the style of graphs, format, colouring and scaling. The most effective dashboards are often the simplest ones, which are displayed on one page summarising the important information (Anonymous, 2010a).

Quality charts

Control charts are important technique for continuous quality control as they are implemented to routinely monitor quality. They trace processes to demonstrate how the process is performing and how changes to processes affect their performance (Statit

Quality Control, 2007). To this end, control charts illustrate the differences of the process output over time and compare the size of these differences against upper and lower control limits to find out if deviation is within the accepted boundaries (Statit Quality Control, 2007). A summary or a snapshot of the result can be displayed using bell-curve type charts e.g. process capability charts or histograms. Control charts may graphically display one or more than one aspects of quality.

Visual safety and security control

Visual safety and security is an important aspect of visual management that adds another dimension to 5S approach of workplace. Visual safety and security helps employees to work safely and aids firms to secure their resources from loss and thefts. Safety signs and error proofing (poke yoke) are substantial visual safety and security tools.

Safety signs

American National Standards Institute (ANSI) defines safety sign as "*a visual alerting device which advices the observer of a potential hazard; the sign should be eye catching and clearly convey the intended message"* (Anonymous, 2010). Safety signs displaying precaution or warning readable or pictorial messages play an important role in accident prevention. Although, there is a trend towards a standard approach to safety signs, customised safety signs that meet individual companies' needs are still important to enhance safe work environment. Safety signs may be in the form of a message panels, signal words and/or a pictorial symbols that might uses various colours indicating different well-known meanings to alert and inform individuals to take precautionary action due to the existence of potential danger or hazards (Anonymous, 2010). Visual safety allows a number of benefits such as enhanced workers morale, compensation cost reduction, downtime reduction and better regulatory compliance.

Poke yoke (Error-proofing)

As previously mentioned, autonomation or Jidoka as lean terms, imply the use of automation with a human sense. Here, four procedures are considered incorporating detecting abnormal condition, ceasing the related activity, taking immediate action to correct the condition and investigating the causes of abnormality and to implement a countermeasure (Breyfogle, 2007). A poke yoke (also called fool/error-proofing) is a techniques used by Toyota Production System that is used with Jidoka to eliminate mistakes or to make them obvious at a glance (Breyfogle, 2007). The idea of poka yoke is simple but useful. It means that "*a careful design of work place, work system and product can minimise mistakes arising from carelessness or depression of employees"* (Ho, 1999, p.22). Poka yoke is most likely used in assembly work and in areas where careless mistakes arise frequently (Breyfogle, 2007). It can be applied in service sector in terms of ensuring proper working methods, techniques and safety procedures. As every day application of poke yoke, everyone who uses ATM card is asked to remove the card before receiving the money that reduces the mistake of losing the card (Scyoc, 2008). Successful implementation of poke yoke requires the involvement of all related employees (Ho, 1999).

Poke yoke can eliminate mistakes through allowing better tracking mechanisms. Taking RTAs as an example, as previously mentioned some companies face significant problems because of RTAs' thefts. Poke yoke might help in eliminating this problem through designing RTAs in unusual shapes that make them hard to reuse for other purposes. If a company faces a problem with incorrect put-away and then misplacement of empty RTAs, poke yoke might allocate different collection points in which empty RTAs should only appear. These points should be clearly seen through painting the allocated floor area in a bright colour. In the case of using different types of RTAs, different bright and shiny colours of RTAs might be useful to easily locate them that also might eliminate the possibility of thefts. The association between RTAs colour and the colour of the floor of collection area make it easier to find them and to put them back in the right place.

4.8.1.3 Motivation approach (Incentive/punishment approach)

Motivation approach is mainly used as an incentive to enhance performance at different levels. Motivation is a mechanism through which individuals, work teams, firm's partners and other stakeholders are encouraged to behave in a certain way to achieve specific goals. Internal incentives that consider firm's internal boundaries take different types e.g. financial and/or non-financial. Non-financial incentive might take a form of personal or team certificates and awards. Visual incentives are important to track success and progress made by individuals and teams. In modern production systems, communication board as a visual tool can display incentives such as employee of the month and team's achievement award to share and celebrate success and to trigger the performance of other individuals and teams. Incentives could be in a negative form i.e. punishment that includes financial and non-financial.

In considering RTAs, incentive approach might be useful to encourage employees to better manage RTAs whether considering individuals or teams. Both positive and negative incentives can be implemented. For instance, financial and non-financial reward might be considered when the loss and/or damage rate of RTAs is significantly dropped.

External incentives are related to firm's external partners. External incentives might be formally agreed within a contractual relationship or informally based on long-term relationship. A firm motivates its partners to energize them to offer better service or products. External motivation incorporates financial incentives e.g. discounts or non-financial ones e.g. providing special service, promotions or technical/managerial support.

Unavailability of RTAs as inter-firm resources causes crucial business problems and bottlenecks across supply chain operations. Incentive scheme might be a useful tool a firm can use to encourage its supply chain trading partners to return the empty RTAs back on time e.g. offering special discount/promotion when certain amount of RTAs are back on time. Although it might not support long-term dyad relationship, formal contract might consider the negative incentive scheme to motivate the return of RTAs.

4.8.1.4 Outsourcing

Outsourcing is another approach a firm might implement through which tracking and tracing activities can be done by a third party. Today's supply chain is managed by the demand side, so that delivery timelines and responsiveness have become key competitive differentiator. This forces firms to rethink about their competitive strategies. Strategic literature has asserted that firms focus on its core competencies and outsource other non-core activities. Logistics function is not considered, in many cases, a core business activity thus, it always subjects to make-or-buy decision (Skjoett-Larsen, 2000; Vaidyanathan, 2005).

Razzaque and Sheng, (1998), Berglund, Van Laarhoven, Sharman, and Wandel,(1999), Hertz and Alfredsson (2003), and Mortensen & Lemoine (2008) intimate to the incremental trend toward outsourcing of logistics i.e. buy decision due to the following factors:

- The company's desire to concentrate on its core competences as well as to actively and timely respond to the market demand that direct all supply chain activities (Horne, 1989).
- Intensive capital is required for managing logistics activities, specifically when considering current features of transport logistics including massive hub DCs, cross-docking, merge-in-transit, and consolidation of various products.
- Logistics function is the key facilitator for the integration of SC activities that requires adopting more advanced IT applications and specialised facilities and skills.
- The complexity of logistics activities along with time compression led to sub-contracting these activities to a third-party logistics who can gain the advantage of economies of scale and scope by introducing integrated services.

Based on two surveys conducted by Elliot, Robert, Martin, and Thomas (1999) and Sink and Langley (1997) identified the main outsourcing logistics functions, Vaidyanathan (2005) classifies these functions into key four areas: warehousing, transportation, customer service, and inventory and logistics management, see figure (4-2). *Warehousing* includes packaging, product marking, labelling, and other warehousing activities. *Transportation* focussed on fleet management, cross docking, and product return. *Customer service* deals with freight payments, auditing, order management, fulfilment, help desk, carrier selection, and rate negotiation. *Inventory and logistics management* is associated with shipment planning, freight distribution, freight consolidation, traffic management, carrier selection, inventory management, and order management. Material flows represent the integration between distribution and transportation activities whilst, information flows indicate the integration between the four categories (Vaidyanathan, 2005).

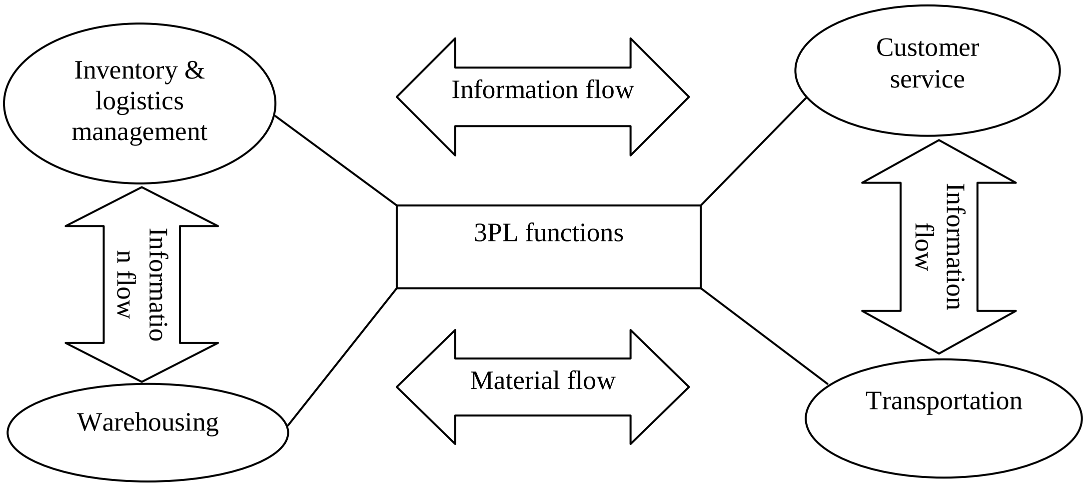


Figure 4-2: 3PL functions
Source: adapted from (Vaidyanathan, 2005)

3PLs are more likely to invest in innovative tracking and tracing technologies to enhance their capabilities for better service. Lin (2007) classifies innovation in logistics technologies according to logistics activities into four groups incorporating *automatic identification technologies* (e.g. bar-codes and RFID); *warehousing technologies* (automated storage and retrieval system, automatic sorting system, thermostat warehouse, and computer-aided picking system); *transportation technologies* (global positioning system (GPS), transportation information system, geographical information system (GIS), transportation data recorder, radio frequency communication system) and *information communication technologies ICT* (electronic point of sales (EPOS), value added network (VAN), electronic data interchange (EDI), extensible markup language (XML), and electronic ordering system).

With respect to RTAs, 3PL plays a substantial role in managing these assets across supply chains especially with the predominance of outsourcing pattern in today's business environment. The extent to which a company has access to tracking and tracing logistics information available at a 3PL's firm may vary depending on a contractual or an informal agreement driven by a long-term relationship. The scope and scale of tracking and tracing logistics information is influenced by the 3PL's organisational, operational and technological capabilities including ICT that facilitate visibility.

4.8.2 High-tech tracking approach

This section draws on various types of more advanced tracking technology including *automatic identification Auto-ID technology* including linear barcode, two dimension barcode 2D barcode and RFID as the key tracking technology with SC applications. In addition, other auto-ID are considered such as optical character recognition (OCR), biometric recognition and smart cards. Location technology is the second type incorporating real time location system (RTLS) and wireless technology and global positioning system (GPS). Finally, automatic visual tracking technology combines closed-circuit television (CCTV) camera, internet protocol (IP) camera and video camera.

This section provides first an initial overview about item coding and identification considering SC context. This is followed by explaining the various types of tracking technology.

4.8.2.1 Item coding and identification

The key mechanism of tracking and traceability at SC operational specifically physical flow level is item coding and identification. Items that are similar in form, function or fit are tagged with similar code (Cavinato, 1984). The role of item coding and identification is to reference associated object information of an object that facilitates information exchange among supply chain partners (van Dorp, 2002). Codes can be found in many forms, but all share similar features such as identification or reference of the producing firm, product family, the specific product, and capacity or quantity. Codes also might contain data about the lead-time, vendor, handling and usage requirements, or government toxic or hazardous labelling requirements (Cavinato, 1984, p.333). The smallest tracked and traceable units are lots and batches that include items sharing the same specifications. Batches are identified using batch number. Batch segregations or pooling that entail changing properties requires new identification number. Item coding facilitates storage and retrieval processes of an object, internal tracking of work in process, stock keeping units, replenishment, check-in/out, sorting of items, and put away activities. Here, tracking and tracing technology plays a key role in determining how efficient these features are.

4.8.2.2 Automatic identification technology

Automatic identification and data capture technologies are able to automate and streamline data entry, minimise labour costs, provide fast, accurate and current information, etc (van Dorp, 2002). Lampe and Strassner, (2003) refer to the key elements of a *good asset management system* that include the ability to manage assets individually; locate the right assets; provide information about the current physical status and keep historical information about assets. These factors are used here to differentiate mainly between barcodes and RFID as the most related systems.

This section discuss the main types of Auto-ID tracking technologies starting with barcodes including linear barcodes and 2D barcodes as the prominent system in supply chain followed by RFID as the most promising Auto-ID technology that is the focus of this research. The section also sheds the light on other Auto-ID types such as OCR, biometric recognition and smart cards.

a. Linear barcodes

Linear barcodes or one dimensional barcodes system has been used in the retail industry since 1950s (Bose & Pal, 2005) and about 30 years ago, barcodes have been used almost everywhere in different kinds of business. Barcodes infrastructure involves barcode readers, tags, and universal product codes (UPC). This version is a traditional version of barcodes system that stored data in the form of parallel lines in different width using universal product codes that could only encode numbers so that it can be read, retrieved, processed, and validated using a computer (Gao, Prakash, & Jagatesan, 2007; Palmer, 1995). Linear barcodes is the simplest and most inexpensive method of Auto-ID technology used in tracking items. Barcodes can be printed on durable materials and are not affected by certain material or electromagnetic emissions that lend them a competitive edge in some industries and environments (White, Gardiner, Prabhakar, & Abd Razak, 2007).

Drawing on the factors of good assets management systems

Linear barcodes have very limited capabilities in achieving these factors, as they have very limited capacity of data storage about individual items. In addition, it is a labour intensive technology, because it needs line of sight to scan items, this requires items to be manually manipulated prior to being scanned that may imply possibility of human error (McCathie, 2004). Hence, managing assets individually is almost impossible task.

Moreover, linear barcodes offer very limited, non-changeable, and constant information about the item (e.g. brand and price). It is also unreadable if tags are damaged. As a result, one dimensional barcodes are not able to automatically locating assets, expressing their current physical status, or keeping historical information about assets. These drawbacks make it very difficult to track and trace high volume items such as RTAs, especially with regard to the moving nature of these assets.

b. Two dimensional (2D) or visual barcodes

The deficiency of linear barcode relating to limited data storage has led to the development of 2D barcodes that can read, store, process large amount of information (millions of bytes) efficiently and error free in a small area (Gao et al., 2007). 2D barcodes can support information distribution, detection, and correction of errors without accessing a database. Product information is encoded in both horizontal and vertical dimensions and the size of the barcode can be increased with more encoded product information, thus the shape of printed barcode is maintained for easy scanning and product packaging specifications (White et al., 2007). Photo (1) illustrates the differences between the layout of linear and 2D barcodes. Since it is designed to detect and correct errors, 2D barcode is readable in the most demanding environment and is tolerant to the dirt, grease, damage (Swartz, 2000; White et al., 2007). 2D barcodes also are able to automatically re-enter long data streams without any human intervention. By using visual or 2D barcodes, it is easy to identify an asset and to allow interaction between the user and the item. Hence, 2D barcodes are useful in warehousing and transportation with regard to the critical shipping information that often becomes separated from the goods transported through the supply chain (Swartz, 2000).

Comparing to 1D barcode, 2D barcode has a greater influence on improving logistics process in terms of receiving and processing goods in transport at very low cost, e.g. shipping notices, returns to vendor, claims and transfer (Swartz, 2000).

Drawing on main factors of good asset management system

Although 2D barcodes have more capabilities and flexibility than 1D barcodes in terms of storage and managing data, they are still limited in the ability to track and trace individual items, especially with regard to lot sizing. 2D barcodes also have limited capabilities to automatically locate items, give information about current physical status of items, and keep historical information.

(1)1D barcode store up to 30 numbers, but a 2D barcode store up to 7,089 numbers
QR-Code.jpg, tribalcafe.co.uk

c. RFID

RFID stands for radio frequency identification, "*a term that describes any system of identification wherein an electronic device that uses radio frequency or magnetic field variations to communicate is attached to an item"* (Asif & Mandviwalla, 2005; Maloni & DeWolf, 2006; Potgantwar & Wadhai, 2011; Want, 2006). RFID is often considered the next stage in the barcode evolution (Srivastava, 2004). Wyld, (2006), Glover and Bhatt, (2006) argue that RFID as a technological asset consists of two main components, First, is the hardware infrastructure that implies tags (transponders), antenna (used in both tags and readers), readers (interrogators) and printers. Second, is the software infrastructure that includes tag's protocol, reader's protocol, and RFID middleware (event manager), that link the RFID components to larger information processing system (Wyld, 2006).

An RFID tag is an identification device attached to the item. The reader is a device that can read the information stored on RFID tag. The reader can then communicate another system to inform it about the presence of the tagged item, this system runs software called RFID middleware standing between readers and applications (Glover & Bhatt, 2006; Whitaker, Mithas, & Krishnan, 2007). According to their source of power, there are three main types of RFID tags incorporating passive, semi-passive, and active.

RFID is considered a revolution in information exchange systems through which every object can be automatically identified, tracked, and traced from a factory to a customer using a single tag attached to individual objects (Sellitto et al., 2007). Cannon and Reyes (2008) argue that RFID is seen basically as a powerful technology for reducing uncertainty in supply chain management comparing to current barcodes system. RFID has a number of advantages that exceed those with barcodes system, see table (4-4), RFID does not require line of sight scanning, minimises labour level, and improves visibility and inventory management (Michael & McCathie, 2005). On the other hand, RFID has some impediments related to adoption cost, lack of common standards, reading issues and privacy concern (Michael & McCathie, 2005); this will be explained in detail later in this section. The following sections draw in turn, on the features of RFID tags.

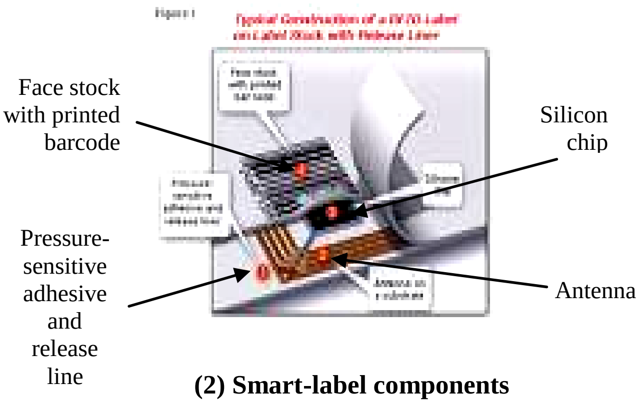
Table 4-4: Comparison between barcodes and RFID tags

Barcode tags	*RFID tags*
Time-consuming reading process as tags can only be read on an individual basis.	Fast reading process because tags are simultaneously read.
Must be visible to be read.	Automatic non- line of sight scanning.
Cannot be read if they are dirty or damaged.	More robust; can deal with rough and dirty environments as tags can be integrated into the packaging materials.
Manual reading incurs labour costs. Automated scanning requires standardization of barcode location.	Automatic reading incurs minimal labour costs.
Tag's stored data cannot be changed unless new tag is used.	Tag's stored data can be changed, if desired, for example temperature fluctuations.
Limited data storage capacity	Data storage capacity depends on the application.

Source: adapted from (De Jonge, 2004; Juels, 2005; McCathie, 2004; Michael & McCathie, 2005).

Passive RFID tag

Passive tag does not have batteries or power source and is powered by the electromagnetic waves sent out by a reader to induce a current in the tag's antenna (Angeles, 2005). Passive tag is on and able to transmit information only when it is within the range of an RFID reader. Photos (2 & 3) show an example of passive tag.

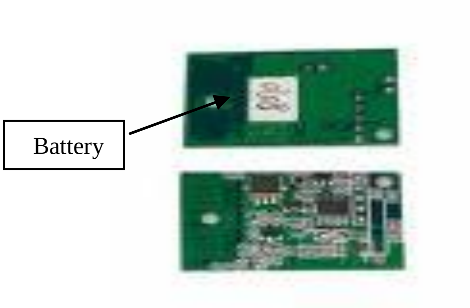


(2) Smart-label components
preview.pffc-online.com

(3) Smart-label
www.100ups.com

Active RFID tag

With respect to active RFID systems, the tags and readers exchange only data, not power. The tags incorporate batteries as their sole source of energy. The on-board battery makes them larger and more expensive (more than $20 each). Because there is no need to get power through a reader, an active tag systems use low-power radio waves that generally create less interference with other wireless networks (Apte, Dew, & Ferrer, 2006). See photos (4 & 5) that illustrate an example of active tag. Table (4-5) holds a comparison between passive and active RFID tags.



(5) Active tag hardware
www.asia.ru

(4) Active tag
www.truemeshnetworks.com

Table 4-5: Specifications of Passive and active tags

Criterion	*Passive tag*	*Active tag*
Power source	Operate without a battery	Powered by an internal battery
Power consumption	Lower power consumption	Higher power consumption
Design	Lesser weight and smaller size	Greater weight and bigger size
Longevity	Endless lifetime	Limited lifetime
Frequency rate	Lower frequency	Higher frequency
Memory	Lesser data storage	Greater data storage
Operating logic	Acquire power from the electromagnetic field generated by the reader	Internal power to transmit signal to the reader
Communication	Respond only	Respond and initiate
Scope of reading	Less tags can be read simultaneously	More tags can be read simultaneously
Transmission rate	Lower data transmission rates	Higher data transmission rates
Read range	Lesser range	Greater range

Sensitivity	Greater orientation sensitivity	Less orientation sensitivity
Reader	Require more powerful readers	Can be effective with less powerful readers
Noise	Subject to noise	Better noise immunity
Cost	Less expensive	More expensive

Source: Adapted from: (Glover & Bhatt, 2006; Miles, Sarma, & Williams, 2010; Weis, 2012)**.**

Semi-passive/active RFID tags

Semi-passive/active tags use both the battery and the waves sent out by the reader (Angeles, 2005). In this type, the RFID tag is conducted with sensor that enabling the semi-passive/active tag to sense the environment. This characteristic of sensing capacity can be functioned for environmental monitoring (Wyld, 2006). Semi-passive tags have a battery that both powers the sensing capability and expands the readability range of the tag. Photos (6 & 7) present a case of semi-passive tag.

(6) Hardware of semi-passive tag
www.dictionary.zdnet.com

(7) Semi-passive tag
www.dictionary.zdnet.com

Table (4-6) shows the main difference among the three types of RFID tags in terms of the frequency ranges and related applications.

Table 4-6: RFID tags' frequency ranges and applications

	Tag type	*Frequency range*	*Max range*	*Applications*
Low frequency (LF)	Passive	30-300 KHz (typically 125-134KHz worldwide)	10 M	Access control; Animal identification; Inventory control; Automobile keys; anti-theft systems
High frequency (HF)	Semi-passive/active	3-30 MHz (typically 13.56 MHz)	>100 M	Access control; Smart cards; Electronic article surveillance; Library book tracking; Pallet/container tracking; Airline baggage tracking; Apparel and laundry item tracking

Ultra-high frequency (UHF)	Active	300 MHz-3 GHz (typically 850-950 MHz)	>100 M	Item management; Supply chain management
Microwave (MW)	Active	>3 GHz (typically 2.45 or 5.8 GHz)	>100 M	Railroad car monitoring; Toll collection systems

Source : Adapted from (Glover & Bhatt, 2006; Rochel, 2005; Wyld, 2006).

Drawing on the factors of good asset management systems

In the context of tracking and tracing individual items, RFID can facilitate enhanced tracking and traceability of assets e.g. components, finished products or RTAs. Michael and McCathie, (2005) stated that RFID is ideal for identifying objects that require routine calibration, inspections, or that need to be checked in or out. The same authors mentioned that RFID can improve availability of assets through tracking their movement, use, and placement.

RFID tags attached to assets are automatically scanned without human intervention. This facilitates locating and maintaining individual physical objects so real time and automated inventory control may be attained (Whitaker et al., 2007). The middleware transfers tag's data to the firm's information system that informs business decision-making process. In addition, tracking-based RFID system can constantly monitor compliance to government regulations and environmental requirements (Michael & McCathie, 2005). To conclude, RFID technology seems to have the suitable technical qualifications for a good asset management system, yet it has some impediments that can be overcome, as it will be discussed latter.

4.8.2.3 Current RFID applications with a special focus on SC applications

The origins of RFID technology was related to the advanced research in reflected power communication made in 1940s (Li, Visich, Khumawala, & Zhang, 2006b). In the late 1980s and early 1990s, RFID has been used for automated toll collections that are widely implemented around the world (Weis, 2012). First commercial applications of RFID were launched in 1994 focusing on automatic tracking of automobiles, rail cars and shipping RTAs (containers) (Li et al., 2006b). The high values of these objects justify the high cost of RFID system.

With diminishing the manufacturing cost, further industrial and transport applications of RFID system has been launched related to lower value objects such as animal identification through attaching RFID tags to pets and livestock. Other RFID applications incorporate contactless payments, airline luggage tracking and building access control. For example, RFID proximity cards are widely implemented for access control at various private and public buildings. Other applications use RFID as an anti-counterfeiting and an authentication tool e.g. for anti-counterfeiting high value monetary notes (Gaukler & Seifert, 2007).

With further dropping in its cost, RFID as a quick response system extended to cover consumers' high value products for inventory control and replenishment in retail industry. Fashion industry is one of the early adopters of RFID as they often face an inventory shrinkage problem. Fashion companies might integrate RFID with electronic point of sale (EPOS) to enhance the performance of SC through being able to generate demand trend and in turn probabilistic demand pattern (Zhu, Mukhopadhyay, & Kurata, 2012). Besides, RFID system has been implemented to ensure authenticity of high fashion products or to improve the shopping experience of customers e.g. the use of smart mirrors or smart fitting rooms that display products details and suggest matching apparel. The future trend in RFID clothing applications is to integrate permanent tags rather than temporarily ones directly into the items or packaging during manufacturing process.

Smart shelves mainly in retail stores is another important RFID application that enables automated replenishment order process either from the store stock to the shelf or from the manufacturer to the retail store (Zhu et al., 2012). In the food industry, the spoilage rate of perishables across supply chains is up to 20% that has been reported by US food and drug administration (Zhu et al., 2012). RFID-enabled automated product identification can substantially diminish the spoilage rate of perishables. In addition, RFID can be applied to ensure the origin or the provenance of products.

RFID is implemented in other business area such as healthcare and pharmaceutical which are promising areas (e.g. medical error prevention, locating staff and assets, patient tagging and blood transfusion and analysis, waste disposal, anti-counterfeiting medication). RFID is also implemented in manufacturing (e.g. tracking manufacturing processes and inventory tracking); assembly (e.g. the assembly of new cars in automotive industry); warehousing (e.g. RFID forklift and warehouse tracking); construction (e.g. tracking tools and equipment on the construction site); travel and tourism (e.g. electronic-Passports and RFID lift system used in ski resorts) and library systems (e.g. book tracking); etc. (Domdouzis, Kumar, & Anumba, 2007; Li et al., 2006b).

It is predicted that RFID will be used in a wide variety of contexts and will affect everyone's live in innovative ways (Chao, Yang, & Jen, 2007; Domdouzis et al., 2007; Zhu et al., 2012). The following table (4-7) summarises examples of current applications of RFID.

Table 4-7: Examples of RFID applications

RFID application	*Example*
Identification and tacking	Livestock using rugged tags, pets with implanted tags, passengers' luggage, athletes in sports and games, children in theme parks, patients, medical equipment (e.g. in surgical medical products to ensure no items left during the operation inside the patient), manufacturing process, assembly, shipping containers, inventory control and replenishment, retail checkout, recycling, waste disposal, etc.
Access control for security and safety	Building access using RFID proximity cards, concert tickets, ski-lift passes, ignition keys of automobile.
E-payment and stored-value systems	Contactless credit cards, automated toll-payment systems, subway and bus passes, stored-value cards, payment tokens (e.g. the SpeedPasstoken for payments in petrol stations).
Anti-counterfeiting	High value currency notes, prescription drugs, luxury products.

Source: Adapted from (Juels, 2005; Li et al., 2006b).

4.8.2.4 RFID-enabling supply chain transport logistics operations

RFID as an inter-firm technology can play a valuable role across a supply chain specifically, inbound and outbound logistics activities that directly affect customers (Zhu et al., 2012). These activities are related to distribution, transportation, and retailing that incorporate asset tracking, replenishment, shipping, receiving, check in/out and putaway. Angeles (2005) asserts that RFID has the potential to enhance supply chain visibility as well as reduce the number and in turn the cost of manual labour work involved in workflow activities. In their study, Sellitto et al.,(2007) conclude that the benefits of RFID are prevalent in transportation and distribution domain in which RTAs are the key transport units. RFID-based RTA systems assist firms and 3PL to better manage their assets and to streamline their supply chain operations. RFID provides confirmatory and accurate identification data about the sealed containers and ideally their content (Schindler, 2003). Whilst the cost of RFID applications may be a barrier to implementation at an item-level, the cost of these applications are economically feasible at an RTA level. Other SCM and stock control tracking applications at an item level require particularly low cost RFID tags and highly technical support to justify their use.

The main applications of RFID-based RTAs within transport logistics include receiving and check in, putaway and replenishment, order fulfilling, shipping and check-out. In this type of applications, the functionality of RFID tags is more than simple identification. For instance, enhanced tracking and tracing of RTAs entails the integration of accelerometer sensors, satellite tracking or tamper alarm within the identification device (Weis, 2012). This enhances the ability to maximise the availability of assets through minimising shrinkage (due to theft, misplacement, and damage), eliminating stock-outs/stock-piles and enhancing asset visibility (Zhu et al., 2012). This section draws briefly on each of these aspects of transport logistics tracking applications.

With respect *to RFID-based receiving and check-in operations*, RFID readers installed in distribution centres can read the tags attached to RTAs once they enter the centre and automatically update inventory quantities without the inclusion of manual labour in check-in and delivering activities. With respect to *putaway and replenishment*, the use of RFID facilitates correct pickup locations without the need to scan items individually that saves time looking for things. In considering *fulfilling of orders*, shop-floor workers will be headed to the right locations to pick required objects that eliminate wrong picking. Thus, the system automatically records the information of picked items and update the inventory record. With regard to *shipping process*, RFID system can enable high speed and error-free automated check-out of loaded shipment without human intervention. Finally, within the *transportation journey* tagged assets can be automatically tracked when RFID readers are installed across a supply chain in shipping docks of major supplier, consolidation points, distribution centres and pool points. Common standards of IT infrastructure for supply chain integration is quite significant to enable asset visibility among trading partners.

4.8.2.5 Challenges of RFID adoption

This section focuses on technical and financial challenges of RFID adoption. The first key challenge is concerned with RFID standards, reading considerations and privacy and security concerns. The second key challenge is related to the cost of RFID systems, the difficulty of allocating this cost among SC partners and its return on investment. The section also discusses the implementation issues from a supply chain perspective.

a. Technical challenges

There are a number of technical challenges hinder the widespread of RFID applications that incorporate the lack of common standards, reading considerations and privacy and security concerns.

RFID standards

To date, there are no general accepted standards for RFID. Common standards of RFID systems (i.e. tags, readers and frequencies) are required to gain maximum advantages across global supply chain trading partners (Li et al., 2006b). The lack of common RFID standards is the key reason beyond the high cost of technology and the elimination of its proliferation (Kay, 2003). It is argued that developing global standards for RFID will ensure interoperability of readers and tags made by various manufacturers and facilitate interoperation across national boundaries as well as facilitate the growth of RFID market (Wu, Nystrom, Lin, & Yu, 2006b). There are two international organisations aim at developing global standards of RFID including Electronic Product Code global (EPCglobal) and International Standards Organisation (ISO) (Wu et al., 2006b). For the UHF band, EPCglobal has developed EPC class 1 G2 protocol, whilst ISO has released ISO-18000-6 standards. These two group of standards were under development and were not totally compatible with each other (Wu et al., 2006b). It is reported that the RFID standards under both EPCglobal and ISO have now been standardised sufficiently, yet they are still not 100% compatible (Ilie-Zudor et al., 2011).

Another concern about RFID standards is related to the lack of unified regulations among countries on UHF spectrum allocation for RFID. These legislations might affect the RFID reading range and speed that add another challenge to the growth of RFID global market. In Europe the use of UHF RFID systems has been limited due to the existing legislation from the European Union (856.6 to 867.6 MHz for UHF RFID) (De

Jonge, 2004; Wu et al., 2006b). In the United States, these systems are already widely used (902 to 954 MHz for UHF RFID).

Finally, certification procedures and power regulations are still incompatible among different nations (Wu et al., 2006b).

Reading considerations

RFID reading is constrained by reading collision and signal interference problems. Reading collision is related to two key problems: RFID tag collision and RFID reader collision.

RFID tag collision occurs when big number of tagged items are simultaneously interrogated by an RFID reader and send their signals back to the reader at the same time (Sellitto et al., 2007; Zhu et al., 2012). This causes confusion to the reader in a way that prevents it from scanning the tags and identifying items. RFID standards offer different solutions to this problem that often occurs with active tags. Besides, some technical solutions has been provided to overcome this problem (e.g. Yang, Chen, & Mao, 2009).

RFID reader collision is caused by simultaneous radio transmission resulting in overlapping among signals from various readers. When a large number of tags needs to be identified simultaneously, it is a serious problem if an RFID system cannot be 100% accurate because it is difficult to identify the tags they have failed to be read. All RFID standards consider a solution for this problem, but additional functionality is often required in the application software (De Jonge, 2004).

Further reading considerations are related to *material effects*. The ability of RFID readers to read through metals and liquids are poor leading to distortion of RFID signals (McGinity, 2008). Finally, RFID readers are only able to read passive tags that face a particular direction, so objects need to be packed accordingly.

Privacy and security concern

RFID readers can read tags without alerting the tags' owners and this violates their privacy and raises security issues. This issue is mainly related to consumer's privacy in retail sector when a consumer buys a product with RFID tag. If the tag is still attached to the product, it continues to be tracked by other RFID readers (Want, 2004). The privacy problems increase when the tags contain personal information such as e-passport or personnel ID cards. National legislation and guidelines of good practices manage the privacy concern of customers (Zhu et al., 2012). For instance, the MIT Auto-ID centre helps Gillette to protect their customer's privacy through the ability to disable the tags upon purchasing at checkout counters. Many studies have focused on RFID privacy and security issues (For further details see, Zhu et al., 2012).

It is reported that RFID privacy and security concern are not yet a major concern due to immaturity and scarcity of RFID infrastructure. Besides, the wide scale adoption of RFID at an item level is still years away. Privacy and security are not only RFID concerns, they are also problems with Bluetooth and WiFi applications especially those related to cell phones (Juels, 2005). When RFID pervasively deploys, a remarkable improvements in privacy and security aspects are expected (Juels, 2005); see future RFID applications section.

b. Financial challenges

There are two key aspects of RFID financial challenges including: (1) RFID cost and the difficulty of allocating this cost to SC partners, and (2) return on investment issues. This section draws in turn on these issues.

RFID cost and difficulty of cost allocation to SC partners

RFID cost implies the cost of infrastructure and the cost of use. The former is related to the cost of readers, tags, input and output devices and associated software and hardware whilst, the latter focuses on the labour cost of customisation, handling tags and maintenance (Ilie-Zudor et al., 2011). The cost of RFID tags and readers along with the lack of standards were the key reasons preventing the deployment of RFID, however the recent considerable development in the technology has led to substantial cost reduction (Ilie-Zudor et al., 2011).

Despite of the continuous improvements in the cost of RFID tags, it is still a major concern especially when considering the item level adoption. In 2000 the cost of an RFID tag was about one dollar whilst in 2005 the cost went down to reach 12.9 cents each (Zhu et al., 2012). It is indicated that the proliferation of RFID would not happen unless the cost goes down to 5 cents a tag (Zhu et al., 2012). A recent study has differentiated between tag's cost and tag's value (Zhu et al., 2012). According to this study, companies should think about the added value when the tag's information is automatically read without labour cost are used effectively. Here, cost-benefit analysis to balance the cost of the tag against its value is needed for efficient decision (Hellstrom, 2009).

It is argued that RFID application across a supply chain is economically viable at the RTA level and would benefit the flow of inter-firm business processes (Hellstrom, 2009). One of the key impediments here is allocating the cost of tags as usually the party who implements the tagging task is not the one who gets the advantages (Holmström et al., 2009). For example, suppliers of Wal-Mart who have been mandated to use RFID tags, attach the RFID tags to the RTAs just before shipping them to Wal-Mart or even outsource this service to 3PLs (Anonymous, 2005c; Gaukler & Seifert, 2007). In addition, manufacturing firms, 3PLs and retailers have different perspectives toward RFID benefits (Alexander et al., 2002). Manufacturers are more keen about tracking RTAs across transport logistics operations whilst retailers are more interested in item-level tracking (Gaukler & Seifert, 2007). It is proved that the differential costs for the upstream manufacturing and the focal organisation is a chief impediment to attain full RFID value at the SC level (Wamba & Chatfield, 2009). The decision about the scope (considered business processes) and the scale (involved SC partners) of RFID adoption and in turn cost and infrastructure need to be strategically made and cooperatively discussed (Ilie-Zudor et al., 2011). Here trust and contracts are important for successful RFID implementation and profit optimisation (Blomqvist, Hurmelinna-Laukkanen, Nummela, & Saarenketo, 2008). Other studies have tackled this issue and have illustrated how the cost of RFID should be shared among SC partners to optimise SC profit (e.g. Gaukler, Seifert, & Hausman, 2007).

RFID business value and return on investment (ROI)

ROI is an important factor to justify any business investment. Investment in RFID technology is a strategic decision that is influenced by company's strategic objectives and plans. As the case with other IT applications, it is often difficult to directly quantify their ROI. RFID benefits can be translated in two forms: *cost reduction* (concerned with cost of labour, inventory and process automation and efficiency improvements, etc.) and *value creation* (related to the improvement in revenue, lead time, responsiveness and in turn customer satisfaction, etc.) (Wu et al., 2006b). In their study, Roth, Cattani, and Froehle, (2008) prove that investments in IT has only indirect impact on ROI through global competence and sales. With respect to a SC context, return on RFID investment is a key concern among practitioners and academics.

Recent studies have focused on RFID business value. The study by Dutta et al., (2007) has investigated three dimensions of RFID value. The first dimension focuses on the implementation architecture of RFID and the resulting drivers of value. The second dimension is related to value quantification and measurement. The last dimension is concerned with incentives to attain information flow. In their study, Wamba and Chatfield, (2009) develop a contingency model for attaining value from RFID in manufacturing and logistics. Their model is built on the framework for IT-enabled business transformation, organisational learning and leadership. The model posits a positive relationship between the level of organisational transformation, derived from the implantation of IT, and the level of realised business value from IT. In the model, five contingency factors affecting RFID value creation within SC incorporate environmental upheaval; organisational transformation; leadership; second order organisational learning and resources commitment. The findings of a longitudinal case data from a Canadian 3PL service company's seven-layer SC RFID projects prove the significance of these five contingency factors for creating RFID value. Another study (Hardgrave, Aloysius, & Goyal, 2008) has shown that RFID can create business value through enhanced inventory accuracy and enhancing in-stock location. Finally, Fontanella, (2004) indicate that RFID can deliver value if it is implemented in a business process that is well-defined and controlled. The same author confirms that firms incur much less implementation risk, gain tangible values and build high capabilities when they take a more focused and simplified perspective in adopting RFID system.

4.8.2.6 RFID implementation issues within a SC context

The research draws briefly on some implementation issues related to the adoption of RFID technology considering supply chain perspective. Ilie-Zudor et al., (2011) indicate three consecutive stages involved in this process including strategic and technical analysis that end with decision process, see table 4-8.

With regard to *strategic analysis*, Ilie-Zudor et al., (2011) consider three factors based on the SC framework of Lambert and Cooper (2000) incorporating SC network structure, SC business process, and SC management components. *SC network structure* determines the actors participating in the SC and how they are linked together and therefore which of them are considered to be involved in RFID initiative. With relation to SC business process, the involved business processes are decided according to those, which add value to the customer and can be connected through RFID technology. *SC business process* determines what information is shared. Finally, *SC management components* are the functions through which business processes are managed and integrated across a SC. SC management components indicate how the information will be used.

In considering technological and financial analysis, the outcome of the strategic analysis informs the second stage which is related to technical and financial aspects. The technological analysis might require developing alternative possible tracking solutions based on different technical requirements considering different types of RFID systems as well as the idea of combining RFID with other systems such as barcodes and other tracking applications. Further detailed technical analysis is required for each alternative solution considering the transformation requirements from the old system that could be manual- or barcodes-based to the new one.

The estimated cost of each proposed solution should be then calculated. This is followed by examining the cost benefit analysis to find out if they are economically feasible and to reach the most cost effective solution (Hellstrom, 2009). Assessing ROI is considered in this stage that might be difficult to quantify. The final part of technological analysis, the conducting of pilot testing of the selected solution is seen as the most important stage (e.g. Angeles, 2005; Robert & Sweeney, 2006). Thus, initial trail should be launched to ensure its practical validity and to deal with the emerging problems whether technical or organisational. Many trials may be required before deciding about deployment.

It is clear that decision process is not a separate phase but rather a process that continues over the implementation stages of RFID solutions. The following table summarise the decision process within the stages of RFID implementation. RFID adoption is a strategic decision that requires the involvement and the support of top management and stakeholders of participating SC partners. The implementation decision entails a balance between technological, financial and organisational aspects. The detailed outcome of

RFID trials should determine the final decision, whether accepting or rejecting the RFID project.

Table 4-8: RFID implementation within a supply chain

Stage	*Dimension*	*Action*	*Decision about*
Strategic analysis	SC network structure	Identify key SC partners; Analyse structural dimensions (i.e. horizontal versus vertical structure)	The number of participating SC partners.
	SC business process	Specify SC business processes	The involved processes within RFID project
	SC management functions	Connect management functions with SC business process	The level of integration of the processes
Technological and financial analysis	Analysis of technical requirement	Translate the outcome of strategic analysis into technical requirements	The technical requirements
	Developing alternative solutions	Analyse developed solution Calculate implementation cost Identify feasibility	The optimal RFID solution
	Testing pilot RFID solutions	Conduct many RFID trials	The acceptance or rejection of a wide-scale RFID adoption

Source: Adopted from (Ilie-Zudor et al., 2011).

4.8.2.7 RFID trends and future applications with a special focus on SC applications

RFID has been classified as one of the ten most significant technologies in the 21st century (Chao et al., 2007). Academic and practitioners' research indicate a rapid growing interest in RFID applications (Ngai, Moon, & Riggins, 2008). Whilst the full potential of RFID has not yet been realised more is expected in the future (Wu et al., 2006b).

RFID has proven its concept in various applications, yet the diffusion/widespread of current RFID applications may need some time to overcome current challenges and to migrate from the dominant barcoding technology. It is argued that in near future, barcode systems will continue operating along with RFID (Chao et al., 2007). With respect to supply chain and logistics, RFID at RTAs level as the most economically and technically feasible application is predicted to grow rapidly over the coming years. Currently, RFID at an item-level is not technically and economically feasible due to limited functionality which eliminates the widespread of related applications (Ilie-Zudor et al., 2011). To date, RFID technology is targeted as an individual application. In the near future, RFID system will enhance its functionality providing multifunctional applications serving quality management, logistics control and decision making, etc (Ilie-Zudor et al., 2011).

The promising technologies related to RFID (e.g. organic components and printed circuits) are expected to significantly reduce the cost of RFID tags that will allow better functionality and a wide-scale applications at item level packaging (Ilie-Zudor et al., 2011; Weis, 2012). For example, manufacturers of packaging could directly print RFID tags into packaging material (plastic or paper) during the manufacturing process. This will eliminate the privacy concern as RFID tags are part of the product packaging rather than the product itself. This development in RFID technology needs years to be economically feasible.

When RFID tags are embedded in most of the objects around, smarter applications are expected. Here are some examples of these applications (Ilie-Zudor et al., 2011; Juels, 2005).

Examples of future Smart applications

Home appliance: home appliances may perform smartly by exploiting RFID tags in food packages and clothes. For example, the refrigerator might alarm the household when the milk has expired or when there is only one carton of yogurt left. It may be also possible to automatically send shopping lists to an online home delivery service. In addition, washing machines might automatically choose washing programs according to the washing instructions on RFID tags attached to garments. In addition, recipe parameters such as baking times could be read and sent automatically to the suitable device.

Interactive objects: smart cell phones may be equipped with RFID readers so that individuals can interact with RFID-tagged objects. They also could scan products and get manufacturer information on their phones.

Shopping: customers in retail stores might be able to checkout just by passing the shopping trolley in front of electronic point of sale, thus all chosen items could be scanned at once. Hence, the total cost is calculated and may charge the customer's RFID-based payment card and send the receipt to his/her phone. In addition, customers could be able to return items without receipt. Data stored on RFID tags would help retailers trace the path of problematic or defective products.

Medication compliance: healthcare is a very promising area for RFID applications. For instance, RFID-enabled drug cabinets could ensure that medicines are taken in a timely manner.

Anti-theft applications: in RFID-based anti-theft solutions, readers may only respond to a given group of tags or identifiers which are not even needed to be unique.

4.8.2.8 Other Auto-ID tracking technology

a. ***Optical character recognition (OCR)***

OCR is "the identification of printed characters using photoelectric devices and computer software" (Oxford dictionary, 2012a). OCR is implemented as an easy and a quick means to transform hard copies text e.g. printed documents and books into soft copies i.e. electronic and editable files for dissemination and processing. This allows publishing printed texts on a website or creating a computerised version of a manual/printed record-keeping system. The first main application of OCR was in processing petroleum credit card sales invoices that allows identifying the buyer from the imprinted account number of the credit card and the transaction information (The Association for Automatic Identification and Data Capture Technologies, 2000). The early version of OCR devices were combined with a punch unit to be readable by the computer. The new versions of OCR devices can directly access computer that facilitates processing of the payment of credit card purchases; this process known as remittance processing. Other applications include page scanners and cash register tape reader. OCR as identification technology can be also used in identifying containers used in air and sea shipping (Bollen et al., 2004). An innovative application of OCR is the use of special scanners that are able to scan pages and convert them to spoken words. OCR is used in production, service and administrative fields. For example, it is applied in banks for the registration of cheques.

The emergence of online systems such as EPOS constrained the anticipated success of OCR technology. In addition, OCR has failed to be used worldwide due to the high cost of accurate OCR software along with the complicated reading process in comparison with other automatic identification systems.

b. ***Biometric technology***

Biometric in Greek means life measurement. Biometrics combines two types including behavioural biometrics and physiological one. Biometric tracking technologies measure a person's unique physiological or behavioural traits to determine one's identity.

These unique physiological characteristics that are regarded as a highly reliable form of identification mean incorporate fingerprint (identifying the fingertip pattern), iris scan (identifying the characteristics of the eye coloured ring), retinal scan (identifying the eye blood vessels), facial recognition (identifying facial characteristics), hand geometry (identifying the shape of the hand), vascular pattern (identifying the pattern of the vein) and DNA (identifying genetic makeup) (Anonymous, 2005b). The behavioural biometric measures the traits that are naturally acquired over time such as the identification of speaker (identifying vocal behaviour), signature (identifying signature dynamics), foot-step (identifying foot-step pattern) and keystroke (identifying the time spacing of typed words) (Anonymous, 2005b; Orr & Abowd, 2000).

Biometric tracking technology has many applications in almost every area. The most popular applications of biometric tracking technology include identifying DNA pattern for security and verification purposes e.g. identifying criminals; biometric devices for airport security, biometric time and attendance systems to control timekeeping of employees; biometric locks and biometric safes (e.g. smart floor system); floor biometric security system for computer access and wireless biometrics for securer and safer transactions through wireless devices (Anonymous, 2005a).

c. ***Smart/microprocessor cards***

A smart card or a microprocessor card is *"a plastic card with a built-in microprocessor, used typically to perform financial transactions"* (Oxford dictionary, 2012b). Smart cards have been around for over two decades and have become very popular all over the world, especially in America, Europe and Asia. Smart cards have many applications in our daily lives incorporating public card-phones, health insurance cards, time registration (flextime), digital signature, debit and credit cards, data encryption, purse cards, personal ID, payment cards, health care cards, transport cards (e.g. Oyster cards used in UK) and mobile telecommunication (Rankl & Effing, 2010, p.7).

Smart cards are able to track and trace the information stored on the cards that vary from one application to another based on different arithmetic processing capacity and memory capacity. Smart cards can ensure a number of security aspects of stored and transmitted information related to integrity, privacy, authentication and confidentiality (Rankl & Effing, 2010).

4.8.2.9 Location tracking technology

Location systems can provide high degree of accuracy of location estimates of mobile objects (e.g. workforce, vehicles and fleet) within an indoor area and/or lower degree of accuracy within a wide coverage outdoor area (Hightower & Borriello, 2001). Extensive and expensive infrastructure is a requirement of highly accurate indoor location systems that rely on wireless technology and real time location systems (RTLS) (Borriello, Chalmers, LaMarca, & Nixon, 2005). Conversely, outdoor location technology doesn't entail extensive infrastructure, yet it might have some limitations, see table 4-9.

Location/mobile tracking applications can provide greater visibility, enhanced responsiveness, improved productivity, effective response to emergency tasks, reduces human errors, optimised utilisation of mobile assets and workforce, enhanced customer satisfaction, instant monitoring of site-based operations and better cash flow (Ennovasys, 2011b).

This section draws on both indoor and outdoor location systems such as RTLS as indoor location system, GPS as the most popular example of outdoor location system and mobile devices as a relatively new trend in this area.

a. RTLS and wireless technology

Real time location systems (RTLS), as local positioning systems, combine complementary technologies that help a company to timely and accurately locate and protect its assets and workforce and in turn to optimise its business process. RTLS systems often use radio signals that are limited to indoor locations due to the short-range reading. Each object has a tag or a badge as an identifier.

The aforementioned Auto-ID is one of RTLS systems which also incorporates other technologies such as Active Badges, Active Bats, MotionStar, Cricket, PinPoint 3DiD and E911 (Hightower & Borriello, 2001). The following table (4-9) shows examples of

RTLS technologies and the associated features including accuracy, precision, cost and limitations.

Table 4-9: Examples of location-based technologies and their features

Technology name	*Accuracy & precision*	*Cost*	*Limitations*
Active Badges	Room size	Administration costs, cheap tags and bases	Sunlight and fluorescent interference with infrared
Active Bats	9 cm (95%)	Administration costs, cheap tags and sensors	Required ceiling sensor grids
MotionStar	1mm (almost 100%)	Controlled scenes, expensive hardware	Precise installation, control unit tether
Cricket	4x4 ft. region (nearly 100%)	$10 beacons and receivers	No central management, receiver computation
MSR RADAR	3-4.3m (50%)	802.11 network installation, approximately $100 wireless NICs	Wireless NICs required
PinPoint 3D-iD	1-3m	Infrastructure installation, expensive hardware	Proprietary, 802.11 interference
Easy Living	Variable	Processing power, installed cameras	Ubiquitous public cameras
Smart Floor	Spacing of pressure sensors (100%)	Installation of sensor grid, creation of footfall training dataset	Recognition might not cover large population s
Auto-ID systems	Range of sensing phenomenon (<1m with RFID)	Installation, cost varies based on the hardware	Sensor location must be known
Avalanche Transceivers	60-80m range	$200 per transceiver in avarage	Short radio range, unwanted signal attenuation
E911	150-300m (95%)	Cell infrastructure or upgrading phone hardware	Needs cell coverage

Source: (Hightower & Borriello, 2001).

b. Global positioning system (GPS)

GPS was developed by the US Department of Defence (DOD) that has become the most pervasive global location technology. GPS is a satellite-based radio navigation system. Earth stations continuously monitor a sum of 24 satellites orbiting the earth (Hightower & Borriello, 2001). GPS receivers located in/with an object (e.g. truck, vehicle, individuals) can detect the signals transmitted by the GPS satellites and compute their location within one to five meters (Hightower & Borriello, 2001). Precision and accuracy of GPS varies based on the type of GPS receivers e.g. inexpensive receivers with less sensing capabilities can determine location within 10 meters with 95% accuracy whilst more capable ones can locate positions within 1 to 3 meters with 99% accuracy. To define the location of an object, GPS receivers capture signals from three GPS as a minimum.

GPS is widely used in vehicle tracking and fleet management. GPS provides real time information about the location of mobile trucks, vehicles and workforce. Most of GPS receivers used in fleet and vehicle tracking are only able to capture data from the satellites, but cannot communicate back with any other satellite or with GPS. In addition, GPS can only compute its position, yet cannot provide further topographical information that can guide directions.

GPS limitations and challenges

In practice, GPS coverage is constrained due to the very weak radio signals transmitted by the GPS satellite that cannot pass through thick trees or buildings (Borriello et al., 2005). Thus, GPS is a very useful outdoor location technology, yet it does not support indoor location systems.

c. Cell phones

Wireless phone service companies are able to estimate the location of phones' users using cell tower observations of cell phones. Governmental regulations in U.S. and Europe have forced the wireless phone companies to be able to estimate the location of cell phones making emergency calls within a 100 meters (Borriello et al., 2005). Cell phones are the most promising location technology as they use the most universal computing platform.

Cell phones limitations and challenges

Borriello et al., (2005) highlight three challenges related to the use of cell phone as location technology. Firstly, privacy concerns as the service provider has the information about the current location of the cell phone users. Secondly, accuracy issues is related to the range of tracking which is 100 meters that might not be accurate enough for some applications. Finally, there is a cost in getting location information as the service provider sells this information for users.

4.8.2.10 Future trend in location tracking technology

According to ABI research, location-based services have grown by 156% from $1.7 billion in 2008 to $2.6 billion in 2009 and it is predicted to be $12.7 billion by 2013 and $14 billion in 2014 (Skeffington & Vant, April, 2010). Borriello et al., (2005) indicate that in the future, the advancement in location-based technology will be affected by the development in the software and hardware of mobile devices specifically cell phones along the advancement in location technology themselves. Although GPS on mobile devices has become more available, not many of the total mobile users use it. In the near future, networks based in 2G handsets will be still the main source of emergency location information (Skeffington & Vant, April, 2010). The second generation of GPS technology with stronger radio signals promises better accuracy and coverage of indoor areas (Borriello et al., 2005). GPS on cell phones can also be coupled with other location technologies incorporating Wi-Fi and Cell-ID to enhance indoor coverage (Prashant, November 2008).

4.8.2.11 Automated visual tracking

Automated visual tracking is "*one of the most important fields of dynamic computer vision and it provides fundamental technologies to develop real world computer vision applications: human tracking and identification, traffic flow measurement and object tracking in smart rooms*" (Ribaric, Adrinek, & Segvic, 2004). The key types of automated visual tracking incorporate closed-circuit television (CCTV) camera, internet protocol (IP) camera. In addition, camera phones are a new trend in visual tracking systems.

a. Closed-circuit television (CCTV) camera

CCTV is a video camera that transmits signals to a limited number of screens located in a specific place. CCTV cameras are used mainly for security purposes e.g. in airports, roads, banks, stores and diplomatic buildings such as embassies and consulates. The biggest number of CCTV cameras installed for public security is in the UK. CCTV systems can also be used in workplaces such as manufacturing plants and warehouses to monitor operations from a central control room. CCTV systems can work continuously or discretely as needed. The advanced version of CCTV is the *digital video recorders* that allow recording for several years with different levels of performance and quality. It also offers more features such as email alerts and motion-detection.

b. Internet protocol (IP) camera

IP camera (sometimes called network camera or webcam) is a digital video camera that allows manual or automatic recording and replaying videos that can be transmitted over internal or external networks through a simple connection to existing Ethernet or internet. There are two types of IP cameras: *centralised IP cameras* that need a central network video recorder to manage the recording video and alarm management, whilst *decentralised IP cameras* have built-in recording functionality that allows direct connection to storage devices e.g. hard disk drives, flash drives or network attached storage. IP cameras give a number of advantages including higher image resolution, flexibility, encryption and authentication, remote accessibility, the ability to work on a wireless network.

Limitations and future application of IP and CCTV cameras

The main limitations of both IP and CCTV cameras are related to the high requirements of network bandwidth, the installation of CCTV and IP cameras for security purposes might be complicated, and special web application security may be required when transmissions of videos is over the public internet. In the future, the use of decentralised IP-based CCTV cameras will support direct recording to storage media devices such as network attached storage.

c. Video camera tracking

Automatic video recording using video cameras is a cost effective and a simple indoor visual tracking tool. Automatic video recording of a workplace enable better management, security and safety practices. Being able to automatically record and display problems when they occur allows quick response and eliminates disturbances. The ability to visually record problems such as machine stoppages, bottlenecks and changeovers helps in the analysis of the causes of these problems, solving them and monitoring the improvements.

Video camera tracking can improve productivity by reducing the labour work for monitoring workplace, enhanced operational practices based on reviewing videos of actual operations. It also can improve safety in remote or hazardous workplaces. In considering the supply chain, authenticity and originality of products can be verified across a supply chain. For example, Asda, One of the UK retailers, broadcasts live videos on its website using network cameras located in its food suppliers facilities (New, 2010).

d. Camera phones

Smart cell phones are coupled with auto-focus cameras, orientation sensor and high speed network access (Chen, Tsai, & Kim, 2010). Cell phones can provide a graphical user interface that can communicate with a company's main server through a high speed wireless network (Chen et al., 2010). These specifications nominate cell phones to play a substantial role in automated asset tracking.

Smart camera phones can work as a barcode reader/scanner specifically 2D barcodes. Scanned data can be linked to a company's information system over the intra/internet and can be virtually stored for further data processing. Location-aware camera phones can also be used as a low-cost asset tracking for the purpose of inventory management (Chen et al., 2010).

Future application of smart camera phones

As a future trend, smart camera-phones will be able to function as an RFID reader that allow self check-out through swiping the phone over the RFID tags of the selected products as well as tracing the history of product's data e.g. its origin and certification (New, 2010). In addition, consumers might be able to instantly compare the prices or rates of a product or may get a detailed review just through photographing the product (New, 2010). The latest RFID readers for smart camera phones enable instant accessibility of any available information on the manufacturer's website.

4.9 Integration of tracking applications

For the sake of maximising the value of individual tracking applications, integration and coupling of more than one application is considered. This section focuses on integration of tracking applications. *Integration* may indicate the use of different applications doing different functions. Here are some examples of integration of tracking applications.

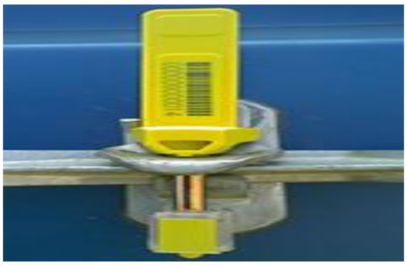
Electronic point of sale (EPOS) and barcodes/RFID

EPOS is defined as "a self –contained, computerised equipment that performs all tasks of a store checkout counter and allows payments by bank or credit cards, verifies transactions, provides sales report, coordinate inventory data, and perform several other services" (Business dictionary, 2012). EPOS data can be integrated with data from barcode or RFID readers. This facilitates tracing a product's journey from the supplier to the warehouse to the store and finally to the point of sale. Tracking data can be used to enhance internal firm and supply chain performance.

EPOS helps retail stores to trace product lines to focus on the more profitable lines, minimise inventory and enhance demand forecasting. If connected with back-office systems, EPOS allows better control over business processes especially purchasing and enhance profitability. In addition, EPOS can be linked to store website to provide instant update of stock information, therefore customers who access the website can know if the product is unavailable and might be offered an alternative. EPOS also facilitates tracing the on-line buying pattern of customers and remind them about the items they used to buy. EPOS coordinates with inventory data to ensure the availability of a minimum amount of stock. In considering supply chain benefits, EPOS helps retailers to streamline their SC processes based on up to date stock data and automatic tracking of fast-moving products for on-time replenishment. EPOS allows tracing sales and purchasing data that if a company shares them with its suppliers, informed demand forecast and plans are in place.

Electronic-seal, barcodes/RFID and GPS

Electronic-seal (e-seal), used as a proof of authenticity and integrity of physical objects, allows automated and enhanced secure supervision and protection. Barcodes and RFID as auto-ID systems can be integrated with e-seal application for enhanced track and trace practices, see photos (8 & 9). In considering high-value shipments, RFID-based e-seal ensures authenticity and traceability of custody across the whole supply chain (Chin & Wu, 2004). In addition, further supply chain visibility can be attained when GPS/cell network can be integrated with e-seals through the visibility of RTAs, trucks and trailers (Ennovasys, 2011a).



(8) RFID e-seal for cargo container

veryfields.net

(9) Barcode e-seal

unisto.de

Cell phones and 2D barcodes/RFID

With respect to the integration between 2D barcodes and cell phones, the advancement in image processing and multimedia capabilities of cell phones, allows them to be used as portable barcode encoding and decoding devices (Gao et al., 2007). The printed picture by 2D barcodes system containing data, that can be photographed by a camera-phone, so that the item's information can be seen. Smart cell phones are quite often used to act as a smart URL that links the user to a particular web page (Ley, 2007). Developments in the range at which barcodes can be scanned similarly reduce the performance gap between RFID and barcodes (White et al., 2007).

In considering the integration between RFID and cell phones, the integration between location-based system for cell phones and passive RFID tags and wireless technology allows better indoor location accuracy (Potgantwar & Wadhai, 2011). This may help overcome some of the limitation of GPS (see GPS limitations section, p.170).

Smart cards and internet-based applications

One of the latest developments in smart cards technology is related integration with internet applications to support electronic commerce payment systems and on-line banking. Smart cards ensure information security (e.g. the use of digital signature in business-to-business and business-to-consumer transactions) and authenticity by verifying that the reader/card-holder is authentic before conducting a secure transaction.

Biometrics and smart cards

Biometrics can be integrated with smart card technologies through storing the unique physiological information of individuals on smart cards. Integrating biometric and smart card tracking technologies allows more advantages. Instead of searching the entire biometric database on a central computer to check the identity of individuals, which is time consuming, smart cards allow fast checking to be done at a station reader (Seymour, Baker, & Besco, 2001).

GPS with GIS, GSM/GPRS

Geographical information system (GIS) is a software offering a detailed map of a city that can allow topographical information of routes and objects' positions (Anonymous, July 2010). GIS when integrated with GPS, the exact or nearby address of the object's location can be determined.

GPS cannot communicate back the location information with satellites, so that it is integrated with global system of mobile (GSM) to be able to send this information back to the main control place. GSM is a mobile communication system that is widely used in most cell phones. Using GSM data call, electronic devices can capture and send some information to central office. GSM is essential in vehicle tracking systems. Another complementary location technology that is recently introduced as part of GSM network is called general packet radio service (GPRS). GPRS add a security dimension over the content of the transferred massages to other GPRS system (Anonymous, July 2010). GPRS does not require additional hardware but it needs advanced GSM software. With respect to GPS, GPRS is not needed for GPS tracking.

Cell phones and Location technology

A mix of location technologies are now integrated in most third generation (3G) or smart cell phones (also called smart touch phones) that reduces the cost of technology and eliminates entry barriers. Cell phones can be used a productivity tool by companies that can enhance the control and management of mobile assets and workforce. Cell phones supported by GPS technology facilitate tracking applications of mobile objects as well as workforce management system.

Mobile workforce tracking applications use a web and GPS or GPRS that are installed on cell phones. These applications offer better management and communications practices of mobile staff as well as paperless work environment. Cell phones can automatically capture transport/travel time and location data that can be monitored using a browser-enabled secure login to the web/private cloud (Ennovasys, 2011b). For example, a new job can be sent to a mobile engineer who receives the details of the job on a PDA (personal digital assistance mobile device using wireless networking and GPS). The engineer can then use GPS integrated with PDA to guide him to the location of the job; the progress of the job is monitored all the times in the central office. Thus, the use of mobile tracking application using cell phones enable effective location tracking, task allocation alerts, task confirmation, task information update, trip track and trace and time sheet management.

Video cameras and RTLS

The new generation of vision devices, e.g. charge-coupled device (CCD) cameras along with computer vision hardware are another efficient and inexpensive form of visual tracking device (Smith, Richards, Brandt, & Papanikolopoulos, 1996). Vision devices can be coupled with other tracking applications providing diverse data on a relatively large areas.

CCTV system can be coupled with RTLS so that CCTV camera can be updated to the control centre room through tracking a tag signal. This enables responsiveness and overall safety and security.

Webcam and E-kanban

For the sake of maximising the advantages of visual tools such as e-kanban, the integration of suppliers and customers using these tools is sought. Industrial customers can see the kanban control boards through a webcam or a network camera positioned on the manufacturer's facility. As such, both parties attain visibility and real-time access to production.

4.10 Coupling of tracking applications

Coupling is more advanced approach that focuses on intelligent product applications in which the individual tracking applications are connected together and automatically update each other (Holmström et al., 2009). It is argued that "a logistics asset that can receive control information from the tracking and tracing applications of the goods it transports would be a step towards simple intelligent interaction between two physical products" (Holmström et al., 2009). For example, Kärkkäinen, Holmström, Främling, and Artto, (2003) examine the use of web technologies and product identification to solve challenges of logistics within international projects. The aim of the proposed system is to "change the controlling mechanisms of project deliveries by giving the deliveries themselves the means with which to control their route" (Kärkkäinen et al., 2003). Another example is introduced in a very recent study conducted by Brintrup et al., (2011) focussed on intelligent assets specifically intelligent self-serving asset that is defined as the coupling of a product and an information-based representation. Intelligent self-serving asset is able to contact, select, and procure service provides autonomously through having a unique identification, communicating effectively with its environment, storing data about itself, deploying a language to present its requirements and characteristics and making decisions related to its own objects (Brintrup et al., 2011).

4.11 Summary of tracking technologies

The following table (4-10) provides a summary of the main features of tracking technologies tackled in this chapter.

Table 4-10: Summary of tracking applications

Item	*OCR*	*Biometric recognition*	*Smart cards*	*Bar code*	*RFID*	*RTLS & WT**	*GPS*	*Camera*
Maturity	✓	✓	✓	✓	✗	✓	✓	✓
High cost as an issue	✗	✗	✗	✗	✓	✓	✗	✗
Existence of common standards	✓	✓	✓	✓	✗	✓*	✓	✓
Privacy as a concern	✗	✓	✓	✗	✓	✗	✗	✓
Needs complex infrastructure	✗	✗	✗	✗	✓	✓*	✗	✗
Works as Indoor application	✓	✓	✓	✓	✓	✓	✗	✓
Works as Outdoor application	✓	✗	✗	✗	✓	✗	✓	✓
Proliferation in SC to date	✗	✗	✓	✓	✗*	✓	✓	✓

Source: prepared by the researcher

Note: WT: wireless technology, ✓*: relatively yes, ✗*: relatively no

4.12 Data quality of the pilot study

Assuring data quality of the pilot study is concerned with establishing appropriate procedures and techniques to meet the criteria of reliability and validity in qualitative research. The research now introduces the procedures and techniques followed in this research to confirm reliability including reliability of measurement instrument and reliability stability and validity including construct, internal and external validity.

4.12.1 Reliability

With regard to *measurement instrument*, reliability was established through the following procedures:

- Asking the same questions of a number of interviewees to reduce interviewees' bias (Voss et al., 2002);
- Using predetermined clearly defined codes that minimised any drift in the meaning of codes (Creswell, 2009);
- Checking transcripts for any mistakes made during transcription. To facilitate the data management and retrieval process, the time shown on the recording device was noted at frequent intervals. An electronic database of the transcripts and observation notes was maintained, and appropriate predetermined codes were highlighted during transcription (Yin, 2003);
- The researcher conducted three site-visits based on a structured approach to confirm the relevance and credibility of the research for informing business practice (Hill et al., 1999).

Stability reliability in qualitative research indicates consistency in the research's approach (Gibbs, 2007). The pilot study findings are not repeatable as they reflect reality at the time they were collected in a situation which may be subject to change (Saunders et al., 2007). Besides, the idea of replicating this type of research is not realistic because the conditions under exploration are complex and dynamic which require a certain level of flexibility. Stability reliability for the pilot study findings might not be attainable unless replication that would achieve the same results is possible. In this research, stability reliability is conservatively attained through the replication of the technique of the study through the three sub-cases.

4.12.2 Construct validity

Construct validity refers to the procedures employed by the researcher to check that the developed operational measures are accurately established for each construct under study (Yin, 2003). The research provided multiple sources of empirical evidence that in most instances supports the theory and justified the interpretations of the data. The research adopted the following procedures to maintain construct validity:

- Triangulation of different data sources (interviews, observations and documents) that allowed a coherent justification of themes (Creswell, 2009; Stuart et al., 2002);
- Mitigating any potential negative effects of interviewee bias by using a site-based case study, supported by interviews conducted with experts in the field;
- A detailed description of the settings of each sub-case and the evidences that influenced the findings was provided, see case description and case findings sections, p. 184 and p.189;
- The use of photographs added a visual dimension that provided additional credibility;
- Each site-visit and interview was conducted by two researchers to eliminate any source of interviewer's bias;
- Analysis and interpretation of the findings were cross-checked by the other two interviewers.

4.12.3 Internal validity

Internal validity reflects the degree to which a causal relationship (i.e. one factor/situation may lead to other factors/situations) can be established (Creswell, 2009). To maintain internal validity the following procedures were followed:

- Investigation of two types of product-based supply chain in different sites with different settings within the same business case allowed the opportunity to measure the research phenomenon deliberately and establish causal relationships through each sub-case;
- As a technique for checking internal validity, *Pattern matching* can provide evidence for a given relationship (Yin, 1989). The conceptually generated pattern (chapter 2) corresponded well with the empirically generated pattern.

4.12.4 External validity (generalisability*)*

Site-based research relying on a single case study, will always have limitations with regard to valid generalisation (Voss et al., 2002). However, it is contended that site-based research using a single case can be powerful particularly if a case is purposely chosen to be non-representative, to examine specific innovative practice (Hill et al., 1999). In other disciplines, it is possible to generalise from one case (Hill et al., 1999). This research is aimed at better understanding the research phenomenon around innovative RTAM practices. As such, analytical generalisation - based on theoretical sampling- not statistical generalisation - based on random samples - can be attained if supported by repeatability through three sub-cases. It is contended that external validity can be achieved if there is a consistency between the emergent theory and existing theory (Barratt, Choi, & Li, 2010). This is confirmed through the interpretation of the pilot study findings, see chapter five, p.198.

4.13 Qualitative data analysis

In this chapter, qualitative data analysis covers the analysis of the case study as a primary data source and field-expert interviews as the source of secondary data along with observations and documents. The data is classified into four conceptual categories. Coding technique is seen as a generic approach for qualitative data analysis that should be combined with another specific data analysis strategy (Neuman, 2006). Coding techniques are applied using 'illustrative method' (see below) as an analytic strategy for the pilot study.

4.13.1 *Pilot* data analysis: strategy and techniques

Of the various analytic strategies for qualitative data, the *illustrative method* is the most appropriate strategy for data analysis in this research. According to this method, data can be organised based on a prior theory that can be in the form of a general model or a sequence of steps (Neuman, 2006). The logic of this analytical strategy is that the research's theoretical concepts are treated as empty boxes; these boxes should be filled with empirical evidences that may confirm or reject the theory (Bonnell, 1980). This strategy fits well with the pilot study stage here as it is informed by an initial conceptual understanding of the research phenomenon. This conceptual understanding is then refined based on the empirical data.

Conceptualisation of qualitative data means organising and making sense of data. The pilot study stage starts with the initial theoretical understanding to be empirically investigated, for detailed discussion see chapter two, p.13. Unlike quantitative research that starts with a conceptualisation which is then made operationalisable followed by data collection, qualitative research begins with data collection followed by conceptualisation and ends with operationalisation based on proposing certain relationship/s. Figure 4-2 depicts qualitative research process.

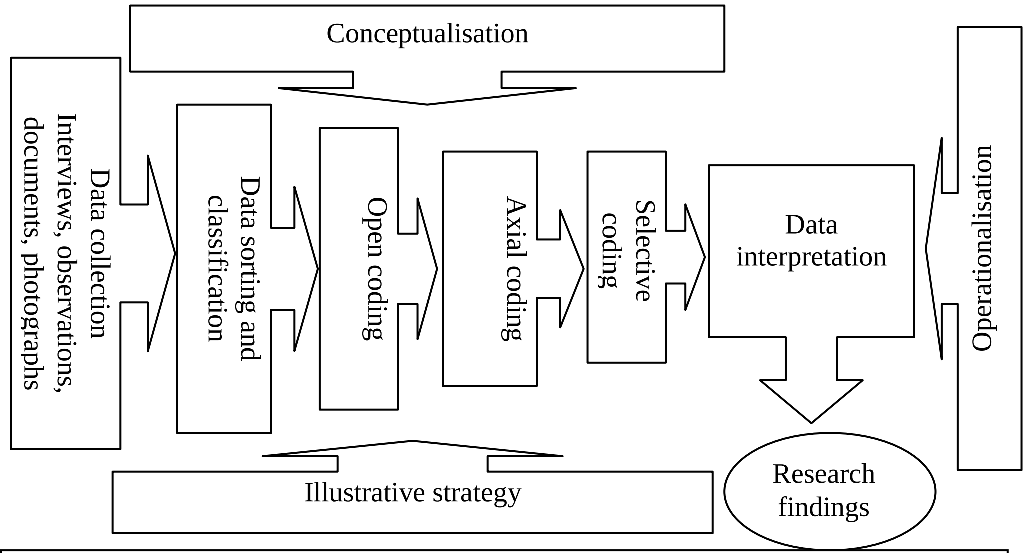


Figure 4-3: Qualitative research process

Drawing on the previous figure, coding qualitative data entails three consecutive procedures: open coding, axial coding and selective coding (Strauss, 1987). In this research, these stages are applied. The use of *open coding* is used to condense the mass of data into preliminary analytical categories or themes and assign codes for those themes (Miles & Huberman, 1984; Neuman, 2006). The themes were developed based on the research questions, theoretical concepts, terms used in social settings and new ideas immersed in the actual data (Neuman, 2006). As such, the initial open codes or descriptive themes were reflected by two key capabilities of asset visibility including technological and non-technological capabilities. Hence, two main categories of data were created; as the second stage, *axial coding* focused on illustrating and re-clustering the concepts/codes represented by themes and making connections among themes (Miles & Huberman, 1984). This entailed analysing each key descriptive theme into sub-codes based on logical links. For example, technological capabilities as a descriptive theme was analysed based on developing two sub-codes: core and complementary technological capabilities. To do this, codes or concepts were organised, logically linked, the refined key themes were highlighted and electronic comments were made that facilitated managing coding process. *Selective coding* is the last step in coding qualitative data by which the previous codes were re-examined to identify data that supported the developed themes. This process involved scanning all the data and the previously developed codes (Neuman, 2006). It resulted in the major themes or concepts that guide the research. Figure 4-3 exhibits an example of coding process.

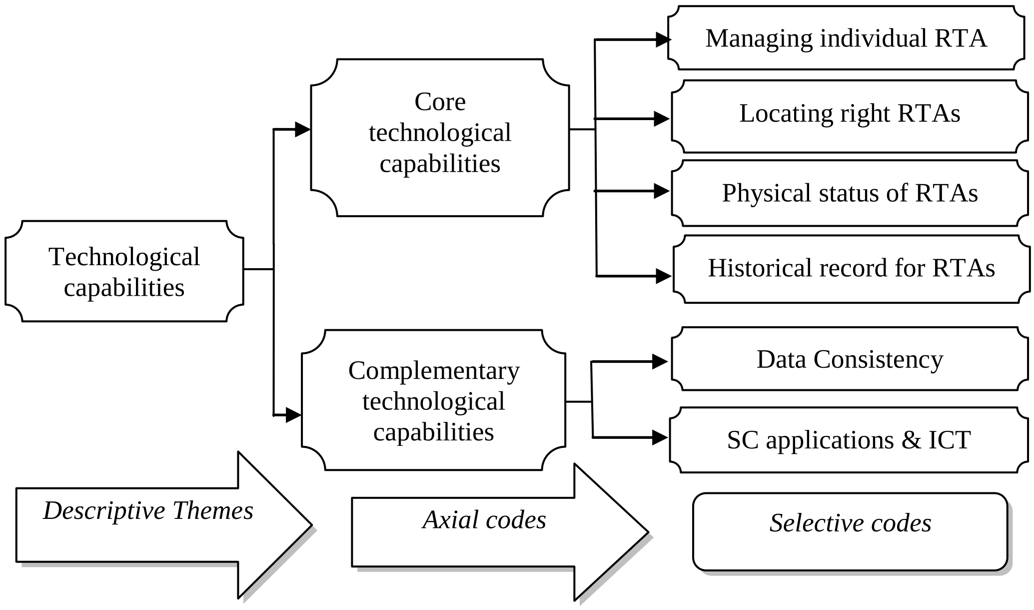


Figure 4-4: An example of coding process

The following sections discuss the pilot data analysis starting with an overview of the main case followed by sub-case description and analysis. The analysis of field-expert interviews is embedded within the case analysis to avoid redundancy.

4.13.2 Case background

TeleCo is affiliated with the telecommunications industry sector. It is considered a large company based on its quantity of employees and on its recent financial indicators. TeleCo offers range of products; telecommunications products, broadband services, internet products and services, IT and network solutions, and mobile services.

TeleCo sought to improve its asset management system especially at the RTAs level. The company developed two active RFID applications for managing its RTAs; one with pallet bins that carry engineers' supplies and the other one with drums that carry various types of copper's cables. Three site-visits were conducted in three different locations as follows.

Location (A) is a distribution centre (DC) which is one of the two key distribution centers in the TeleCo supply chain and is the hub of the pallet bins tracking project; Location (B) is a hub compound for cable drums in which the RFID project was established managing wooden-drums; Location (C) is a depot for cable drums where the RFID-RTAM system was installed.

The researchers' had six semi-structured site-based interviews with the TeleCo supply chain transformation manager and Supply Chain Mentor from the same department. Another two interviews were conducted with two people on the operational level holding a Yard Marshalling position. These individuals are responsible for managing the cable drums in locations (B) and (C). The RFID solution provider was represented and interviewed during the site-visit in location (C). As such, a group discussion was conducted which allowed various internal level perspectives and an external perspective to air their own views on key issues.

In the following sections, the research describes the two key sub-cases representing two types of product-based supply chain conducted through the three site-visits.

4.13.3 Case description

This section provides detailed descriptions and supporting photographs of the RTAM operating system at each individual site.

4.13.3.1 Pallet bins (location A)

TeleCo has its own in-house logistics network that serves 8 main transport depots. These transport depots use a cross-docking distribution system (defined as "receiving a product from a supplier or manufacturer for several end destinations and consolidating this product with other suppliers' products for common final delivery destinations"); its crux is not keeping stock but transhipping (Kinnear, 1997). They have their own network connecting these transport depots to enable communication. TeleCo owns the distribution centre (DC) in location (A); it was set up ten years ago. The DC in location (A) is the hub of the supply and re-supply of engineering supplies. Bags containing engineering supplies are shipped out individually to the warehouses, identified with labels and carried in pallet bins for shipping; see photos (1), (2).

(11) Pallet bin worth £125

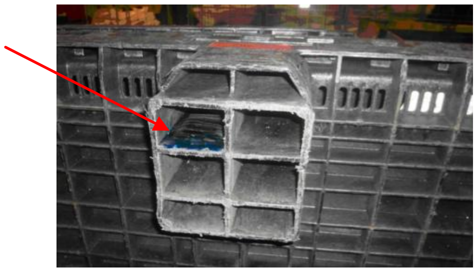
(10) Engineer's supplies in a white bag

These white bags are shipped to ten warehouses from which the engineers can obtain their orders. TeleCo supply chain partners (SCP) originally purchased 1200 bins. After carrying out a six monthly audit, 350 had been misplaced. TeleCo SCP has developed a labour intensive and largely paper driven solution to prevent losses occurring. When losses occur, TeleCo SCP generates an invoice for lost items to the depot allocated the bins. TeleCo SCP was seeking a solution that would automate the track and trace of their pallet bin assets. The solution required had to be robust enough to support the issuing of invoices and to avoid costly disputes. TeleCo SCP attempted to mitigate losses by assigning each depot a set of pallet bins. These pallets bins are then used to transfer stock to the depots. Each depot, including DC in location (A), may supply equipment to sub-depots.

As a result of inaccurate manual reporting of the delivered and returned numbers of pallet bins and the lack of asset visibility, insufficient numbers of pallet bins were occasionally available to the hub DC for continuing shipping goods. This unavailability of assets obviously led to delays across TeleCo's supply chain resulting in the costly exercise of acquiring alternative pallet bins; in addition fines and penalties for delays had to be paid internally.

Drawing on a technical report provided by the relevant supply chain Manager, TeleCo's SCP sought a solution that can meet their requirements which means that it should be able to: (1) remove all or a majority of the paper driven system; (2) uniquely identify every pallet bin; (3) remove the need to specify a set of pallet bins per depot; (4) Automatically generate an alert when bins exceed an expected time of delivery; (5) automatically generate an alert for pallet bins exceeding an expected time of return to the DC in location (A); (6) Associate pallet bins to a trailer on departure; and (7) add an element of accountability to the night trunk process.

The RFID application was installed by an IT solution provider who specialises in delivering RFID solutions. Active RFID tags were attached to pallet bins, trailers and vehicles allowing TeleCo's SCP to identify the current position of the pallet bins. The automatic scanning of data stored on RFID tags happens when assets pass through read zones at the entry and exit points of the sites' gates. For security purpose, there are two read zones i.e. the readers read through a red zone outside the firewall of TeleCo's network and a green zone within its network. Photo (3) shows the active tag attached to the bottom of a pallet bin. Photo (4) illustrates the reader attached to the hub's gate.



(13) An active tag attached to a pallet bin

(12) RFID reader fixed on the gate

The RFID project was fully implemented in 2004. The cost of each pallet bin was 125 pounds, the cost of the active tag was 25 pounds, and the largest cost was associated with the RFID readers which was 10,000 pounds (in total).

The technology adopted is consistent with that chosen for the cable drums tracking project reported below, allowing the projects to converge to provide a coherent asset and inventory management solution across TeleCo's supply chain.

4.13.3.2 Cable-drums (locations B and C)

Sub-case (A) focused on understanding the technological aspects of TeleCo's RFID tracking application system. In the second sub-case, conducted in locations (B) and (C), the research focused on the managerial practices of the RTAM systems and their relationship with supply chain visibility.

Cables are used nationally throughout TeleCo's operations. The company has five main compounds for copper cables. The RFID initiative was launched because they faced problems with tracking cable-drums. The cost of the drums themselves ranged from 200-400 pounds, while the cost of the associated copper cables ranged from 5,000-

10,000 pounds. TeleCo rents the wooden-drums from its supplier. Under the paper-based control system, losing a cable meant losing all the information related to it e.g. its type or the job for which it was assigned. The business had no visibility of the lost cable which meant that even ordering a replacement for it was guess work.

Copper cables have a strategic importance for TeleCo as they are used across the whole country. If the cable ordered for certain job is lost this means accruing high costs in terms of cost of the cable itself (average 5,000 pounds) and the additional cost of not being able to do the job (which could be another ten thousand pounds: source interviewee). There was also the cost of the negative impact on TeleCo's company image and reputation and brand. Although it is an in-house logistics supply chain and the company has full control over its logistics process, it had problems with its supply chain. These problems related to delays in lead-time, high inventory cost, buffer stock, low cash flow, inefficient warehousing (e.g. no enough space for high stock), losing the visibility of the entire supply chain, inefficient order system, liability cost of being not able to do the job on time (e.g. holding roads, waste time, penalties, bad reputation), so that quality of information was missing.

TeleCo conducted two pilot studies with RFID project for cable-drums in two locations in 2004. In location (B) the application started in June 2008. The RFID Solution Company is the same provider for the pallet bins project. Set up cost in both locations was 10,000 pounds on average. The system is managed using active RFID tags that are especially designed for the company in South Africa. They needed the tag to be slim, so that they were able to fix it to the drum with a screw to enable it to be reused, see photo (5), (6), and (7).

***(14*) A copper cable worth £10,000**

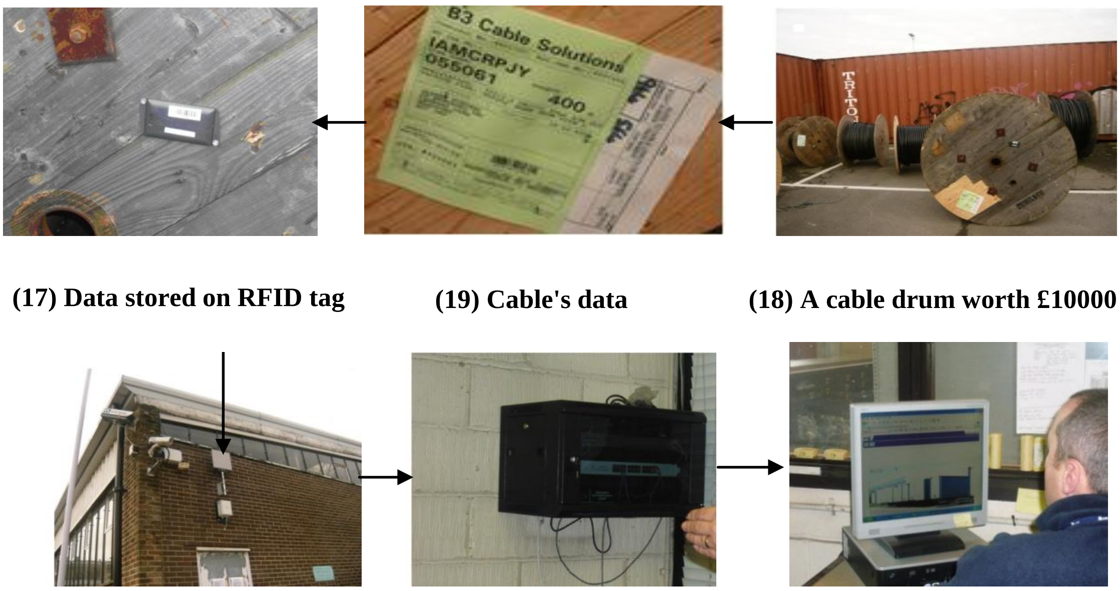
(15) An active tag on a

(16) A trailer carries 200 drums

The cyclical loop of the drums are as follows: (1) the supplier sends cable drums to the company; (2) RFID tags are fixed on the received cable drums; (3) the RFID tags are taken off the drums upon its return on completion of the task and remaining cables are scraped; and (4) the drums are collected ready to be sent back to their supplier. The company keeps historical records of information stored on RFID tags. RFID tags are reattached to a new cable-drum. The RFID Solution Company has shared the risk of using these customized tags through reducing its price from 25 pounds to 7 pounds.

The type of tags used is a European tag standard. Technically, RFID application is a little different with the cable drums project. Here they have only a green zone for reading. The reading is captured through the main server which is directly connected to TeleCo's information network. The logic of tracking here is based on "last time the asset was seen". Figure 4-4 illustrates the logic of the RFID based RTAM system.

In supplying *cable drums*, TeleCo faces high volume fluctuations from day to day. In the observation period they were receiving 8 trailers in location (B), this has now reduced to 6 due to the recession. Each trailer carries about 200 drums meaning they handle about 1200 to 1600 drums a day with the ability to be used.



(17) Data stored on RFID tag **(19) Cable's data** **(18) A cable drum worth £10000**

(20) An RFID reader reads data **(21) A server transfers data** **(22) Information visibility**

Figure 4-5: Cable drums management system

The next section introduces the case analysis based on the employed analytical strategy and coding techniques.

4.13.4 Case findings

Drawing on the supply chain visibility literature, the research conducts a twofold analysis of the empirical data: technological and non-technological capabilities of supply chain visibility (Barratt & Oke, 2007). Relying on ERBV as the adopted theoretical perspective, these capabilities are in turn classified in terms of core and complementary capabilities. Table 4-1 illustrates these key themes and associated developed operational measures.

Table 4-11: Pilot study findings

Key dimensions of pilot study findings	**Developed operational measures**
Core technological capabilities	
"*When the engineer put in an order for a cable; the cable came to one of our compounds. If the engineer did not come to collect it no one knows anything about its existence whatever period it was there for"* Supply Chain Manager. With the adoption of a tracking system using robust RFID tags, Teleco is now able to identify specific pallet bins ensuring engineers are assigned the right materials, saving significant cost and time. All the information related to their RTAs or related to individual white bags or cables are stored on the RFID tags. Hence, information about the items (white bags) and RTAs can be identified across the forward and reverse supply networks. These tags have greater capacity to store detailed information of returnable assets. The manual system meant containers were unavailable, jobs associated with these containers were delayed or contingency cable had to be ordered increasing inventory and materials handling costs. Reflecting on the manual tracking system, a Field expert suggested "*companies rent or own on average up to 30% more assets than are needed*".	Ability to manage assets individually;
Reflecting on TeleCO's previous manual tracking system: "*To find the right RTAs, it was very time consuming given that there were 200-300 cable drums in an open reach area*", Supply Chain Mentor As observed in location B, an engineer came to collect his order (cable-drum), the Yard Marshal could find the right cable quickly through scanning all the RFID tags in the open reach area or the storage yard (an area in which all cable drums are consolidated). The engineer was able to collect his order on time with almost no paperwork. Before collection of an order was time consuming and sometimes engineers queued a long time for	Ability to locate the right assets;

their orders. Now all the administration work is processed through the TeleCo information system. "*Advanced data capture technologies like RFID can enhance the efficiency of a supply chain by always having the right objects available on time and in the right location*" Field-expert	
TeleCo faced a problem with maintaining the quality of its RTAs specifically pallet bins. With the previous paper-based tracking system, no one had responsibility for these assets, the paper-based system did not offer accountability for causing damage, misplacement or misuse. In addition, it was not possible to associate any of these problems to any individual. "*Availability of pallet bins and wooden drums in a good condition is crucial for our business*" Supply chain Manager The current asset management system allows traceability which added accountability as well, through being able to allocate responsibility for damage or other quality issues. This accountability significantly reduced the cost of replacement and repair. In addition, the awareness among engineers and staff of the need to maintain these assets has increased.	Ability to provide information about current physical status of an asset;
The current tracking system provides TeleCo with the opportunity to trace their RTAs and the items carried in them through keeping a historical record of each RTA. The information recorded indicates which wooden drum or pallet bin was assigned to which cable or white bag as well as providing details pertaining to the job that the cable was allocated for including job due date, job number, location, order number, cable length, scrap etc. Retrieval of these details is possible whenever required through accessing the company's database. This was impossible with the old manual system. Better traceability of the company's assets has led to better capability in controlling and managing their supply chain operations through better stock management practices. In addition, they have improved related security issues. RFID allows automatic tracking without human interaction. This allows full control of RTAs specifically during the night when the site is unmanned. If a carrier came and collected from the compound, the system registers and stores the details of the taken drums. As such, they can automatically monitor the system at any time of the day. Under the manual system it was a major issue when a cable drum was lost, as there was no mechanism to identify missing cable.	Ability to save historical information about an asset.
Complementary technological capabilities	

As observed in the three sit-visits, TeleCo now has an established IT and ICT infrastructure which connects up geographically dispersed sites and departments. To facilitate communication between various users, a unified language and format are used. Different supply chain applications are in place such as a continuous replenishment program (CRP) and resource planning applications. Employing the current RFID system entailed installing a new IT infrastructure (mainly the RFID tags and readers) as hardware components and RFID software to link the RFID components to TeleCo's larger information system. The output of the RFID system is in an unreadable format, so that the company's server translates RFID data into a readable language. With this readable data, communication and information sharing with other supply chain applications can occur. The visibility offered through the RFID tracking system has been accompanied by improving other IT systems. For example, implementing a new online system for ordering fast moving items through which engineers can place their own orders. This system also offers visibility, engineers can have their orders delivered to the nearest warehouse on their route reducing delivery time, operations cost and improving performance for customers. Such integrated visibility based on up to date and accurate information about product details and position has offered more flexibility in managing Teleco's supply chain operations especially fulfilling orders, replenishment and transport logistics activities. The overall result is shortened delivery time for many jobs which has maintained better relationships with TeleCo's customers. TeleCo is about to fill the missing link of complete asset visibility through planning to use a transport tracking system, specifically the geographical positioning system, GPS would generate visibility over all the transport logistics operation. An initial trial has been successfully conducted. "*GPS will help us to have visibility over transport journeys…..we aim at more flexibility in managing our transport fleet that saves us time and money*" Supply Chain Mentor. Field-experts have indicated that no benefits can be expected from using advanced tracking systems unless an appropriate and compatible IT infrastructure is built. ICT is crucial for sharing information across supply chains. For IT applications, no magical solution exists to suit all companies. The key concerns are what the company exactly needs to achieve by applying certain technology and how this IT application can integrate with other applications. Here the IT solution company plays a key role. This is why IT applications are customised, not ready-made. One interviewee commented that different standards, specifications and levels of implementation mean different expectations from technology among supply chain partners. This variation might affect the level of integration between	IT infrastructure for supply chain integration

partners and in turn performance. Implementation of RFID across a supply chain should rely on agreed standards among partners. Cost of technology is still a major concern that justifies the reluctance of adopters to share information.	
Core non-technological capabilities	Ability to reduce delivery and return time;
Unavailability of cable-drums was the key challenge the company faced, which created costs such as assigned jobs not being completed on time, additional financial penalties and also negatively affected the company image and reputation. Visibility of cable drums and pallet bins facilitates TeleCo's logistics processes and reduces lead-time. Load preparation, loading, unloading, check-in and check-out activities; all mostly performed automatically with little human interactions. This reduces lead-time across TeleCo's supply chain especially when used in conjunction with improvements in other systems such as online orders and stock management. In the tracking system, the return of empty items (i.e. pallet bins and wooden drums) caused lots of problems especially the wooden drums provided by the cable supplier. As previously mentioned within the case description, the company lost or misplaced 350 pallet bins in only six months. TeleCo suffered from delays in the return of these reusable items that no doubt affected the flows of its logistics operations. Critically this also negatively affected the relationship with the cable supplier who could not get his items back on time. These disturbances of the reverse physical flows led to delays and disturbances across supply chain operations. As observed in site C, wooden drums were consolidated ready for collection to go back to the cable supplier who was informed in advance about the availability of drums. In the previous scenario, the company cannot say exactly when the items will be available. The visibility offered by the new tracking system has allowed reliable return time. If the item does not return back as scheduled, based on the logic of "last time the item was seen" the manager can identify the item's location and allocate responsibility for the delay.	
The flexibility offered by visibility of engineers' orders accompanied by the visibility of RTAs eliminates pick up and drop off errors. This was an issue under the manual system. TeleCo's Supply Chain Manger has drawn on the previous manual system: the engineer might collect the wrong item and only after all the time spent setting up a job, discover that the wrong items had been sent. The job was then delayed until the right items were received and shipped. The set up costs for closing roads, highways and pavements	Ability to eliminate delivery and return errors;

are substantial. In addition, another job might not be completed because the wrong item was originally assigned to it. This badly affected TeleCo's reputation in addition to related financial obligations. Currently, received or delivered items are checked through the company's database before leaving the site which automatically updates all related information. This eliminates the possibility of delivery errors and offers reliable delivery. The return of empty RTAs faced the same problem mainly related to the wrong number of items returned, this problem was directly concerned with loss or misplacement. The current RFID tracking system provides more control on RTAs across forward and reverse logistics operations. Field-experts have clarified that the use of cross-docking systems accompanied with consolidation of different products increases the possibility of wrong delivery especially with a paper-based tracking system.	
"*We were ordering an emergency cable while we have it but we do not know where it is because there was no visibili*ty*, now we know what's where".* Yard Marshall. Under the manual tracking system TeleCo's engineers tended not to spend time looking for the right cable drum assigned to their jobs especially with the high numbers of cable drums in open reach area; (100-300 cables). They would instead just get the closest cables regardless of the length required for their jobs. This caused TeleCo many problems including waste of resources and in turn, shortages in operational supplies that entailed reordering new cables. This resulted in inefficient use of engineers' budgets due to the quantity of high cost emergency orders. Replacement of damaged, lost or misplaced returnable assets was a regular activity to face the shrinkage of these assets across TeleCo's supply chain. The visibility of supply as a result of the new tracking system has helped the company to stop these irresponsible and inefficient practices. Visibility of returnable items has resulted in improvements in other systems, for example the scrapping system is far more accurate and therefore able to make use of cable ends which would previously have been wasted. As observed in Location B, a drum came back after a job was completed, the Yard Marshal scanned the RFID tag and so knew which job it was assigned for, how much cable had been used and how much remained. Hence, the remaining cable is measured and scraped where appropriate. This information is visible through the company's database, so that longer lengths need not be scrapped and are re-used in further operations.	Ability to efficiently manage resources.

The poor visibility of TeleCo's returnable assets accompanied by uncontrollable put-away activities led to the possibility of thefts and loss. TeleCo's lack of reliable information meant it regularly faced stock-out and stockpile problems, invisible stock, failure to assign the responsibility of loss causing disputes and low cash flow. The current tracking system has helped the company to have better visibility of recent supply chain operations informed by reliable and accurate asset tracking information. "*Information created by the RFID system is quite intense….filtering this information is the only way to make use of it*". Field-Expert TeleCo's Supply Chain Manger illustrated that the company could filter the throughput of the tracking system with the help of the RFID solution provider. For example, to reduce the amount of throughput of the RFID system, the reading frequency of RFID tags attached to returnable items have been set up at a rate of one every ten minutes instead of performing continuous reading. To avoid losing control on the items between the periods of scanning, RFID tags are attached to TeleCo's trailers as well. The readers on the site's gates instantly read the in/out activities of these trailers. As such, the accountability element is established as they can associate any loss that happens to a specific trailer.	Ability to have reliable process information;
Complementary non-technological capabilities	
Because of the poor visibility associated with manual tracking, TeleCo could not share accurate information with their strategic suppliers or internal and external customers about logistics operations, specifically the physical flows of engineers' supplies and cable drums. The problem was augmented because of poor visibility of the stock holdings which resulted in a high level of inventory keeping units. Engineers used to have lockers as delivery points to collect their orders. They misused these lockers as they used them as a storage facility to store items instead of picking orders, so that visibility was lost (and overall stocks increased) as there were no records of these additional stocks. The locker system was changed and a new system replaced it (a Kanban system) that offers more flexibility in that orders can be collected from the nearest warehouse or depot. As such better inventory management practices have been implemented. Improving the inventory system and tracking system resulted in minimising the inventory holding or stock keeping units. The manager of the key distribution centre of fast moving items (engineers' supplies) stated; "*Asset visibility helped us to reduce our inventory by 30%".* The Supply Chain Manger confirmed that better information sharing practices with key suppliers relating to delivery and return arrangements of	Ability to have external supply chain process integration;

products and empty wooden drums are now in place. Positive feedback from customers regarding performance and specifically delivery has been received. TeleCo's manual tracking system caused a lack of visibility over the return of empty assets that meant TeleCo were not able to tell the cable supplier how many empty drums were ready for return postponing related financial processes e.g. issuing invoices and causing disturbances in the drum suppliers' processes that negatively affected TeleCo's relationship with its suppliers. TeleCo's Supply Chain Mentor confirmed that more reliable delivery of jobs and a more reliable return of containers has ensured better financial transactions. This has strengthened TeleCo's relationship with its major suppliers and has offered a greater opportunity for better collaboration especially related to delivery schedules and sharing the experience of the new tracking system. Field-experts have explained that in the current scenario, the progress of supply chain operations is expressed through the progress of orders i.e. financial flow rather than the actual physical flow of products. The only way to attain asset visibility across the supply chain is through establishing integration mechanisms, especially at the product flow level considering the different parties such as manufacturer, distributer and customer. Innovative tracking technology can facilitate this integration which is conditioned by simultaneous adoption of the technology. Field experts have indicated that sharing the cost and the return on investment of technology is a constraint for the wide adoption on supply chain level.	
Field-experts illustrated that improving the tracking system on RTAs is substantial for logistics companies (3PL). Now more RFID initiatives are taken by 3PL who wants to control his logistics activities that, in most cases, are geographically dispersed. This is also associated with the current trend towards consolidation and cross-docking practices. Returnable assets are crucial for a smooth flow of transport logistics operations. Loss and damage of RTAs are daily problems for logistics companies who sign contracts to complete services on time. To avoid financial penalties due to delays, new items are ordered to fill the shortage in RTAs supplies which is quite costly. Drawing on a business case representing a logistics provider given as an example by a field-expert "*The company was replacing annually 150,000 units that were reported as stolen or missing"* Field-expert To improve their performance and in turn to better serve customers, logistics companies have a variety of tracking technology choices based on different specifications and qualifications e.g. 64-bit vs. 96-bit tags. Here,	Ability to establish a strong relationship with the 3PL;

the IT solution provider plays a crucial role in finding the best solution to match the company's needs. The cost of the technology varies and is still a debatable issue among practitioners. When a logistics company makes a decision regarding the adoption, it initially completes a trial, then, depending upon the results, a final decision is made. Many companies especially in the retail industry have perceived benefits and return their investment into the system or more than that. Field-experts reported that successful implementation of the automated tracking system has the ability to help assist a company in gaining a competitive advantage over its peers. Field-experts have explained that when the adoption of tracking technology is an initiative by the 3PL, sharing tracking system information with other supply chain parties might be problematic and restricted because of the technology adoption cost incurred by the 3PL. The 3PL might be willing to share information with strategic shippers and/or consignees in order to build strong relationships. "*Manufacturers might obtain online access to the logistics companies' delivery schedule, so that they can estimate the arrival date and time of the products to their destinations"*, Field-expert The 3PL may also help manufacturers to improve their internal logistics processes; for example educating them about the RFID tracking system or other relevant system. The size of the shipper firm and the length of the contract, affect the level of co-ordination that might range between sharing basic information to customising the service. Field-experts have referred to the Wal-Mart scenario where the implementation of the tracking technology is forced by a powerful manufacturer or retailer, here the cost of the RFID infrastructure is shared between three parties i.e. manufacturer (shipper), 3PL (distributer) and retailer (consignee). All parties must share information in order to improve the performance of the whole value chain. If co-ordination practices are established, simultaneous adoption of tracking system results in a high level of supply chain visibility, maximising the return on investment for all parties.	
TeleCo's internal integration seemed to be an influential factor on the level of information sharing (communications channels between different departments and functions including resource planning, purchasing, distribution and warehousing allowed better management practices). For example, the planners are currently able to make the decision regarding the quantity of cable required for the next operational plan in the light of the visibility offered by the supply chain department based on reliable inventory information. As visibility was perceived as a means to improve	Ability to establish internal integration

TeleCo's performance, higher management have encouraged internal collaboration practices. Visibility facilitates co-ordination and collaboration between warehouses. In the manual system, various locations of the company appeared to be isolated entities compounded by their geographical dispersion. Observed in location B: the Yard Marshal received a phone call from another warehouse manager requesting a check on the possibility of collection of specific items for an order. The warehouse Manager was able to respond confidently due to the visibility offered by the new tracking system that the items were available in depot B. Better internal integration enhances TeleCo's performance in terms of reducing the shipment processing costs, lead-time and inventory holding throughout the supply chain.	

4.14 Summary of the chapter

This chapter provided an overview of different tracking and tracing systems and then presented descriptions and findings from the pilot study. The chapter defined and differentiated between tracking, tracing and visibility concepts considering different perspectives. Examples of tracking applications were presented. The chapter explained the key business problems associated with poor tracking practices, with a particular focus on those related to RTAs tracking and tracing practices. In addition, the merits of tracking, tracing and visibility in general were discussed as well as those specific to tracking and tracing of RTAs. The chapter discussed in detail the low-tech versus high-tech tracking systems. The chapter then pointed out the idea of integration and coupling of tracking applications, and provided a number of illustrative examples. This part of the chapter was completed by a summary of the key features of tracking applications.

In considering the pilot study findings, the chapter highlighted the main procedures followed to ensure data quality aspects of the pilot study. The chapter provided the context and background to the overall case organisation, TeleCo, and details regarding the individual sub cases within TelecCo. Towards the end of the chapter, key findings of the pilot study were presented. A summary for the chapter was lastly introduced.

The following chapter discusses the key findings of the pilot study through which the initial conceptual model is refined and theoretically expanded to cover the impact of asset visibility on sustainable competitive advantage. In addition, hypotheses are developed.

Chapter 5: Pilot discussion and the refined research model

5.1 Introduction

The purpose of this chapter is to discuss the pilot study's findings and to refine the research's initial model. The pilot study discussion is concerned with exploring the capabilities pertaining to asset visibility and their impact on supply chain visibility (SCV) and firm performance. This discussion is also supported by the relevant academic literature in the operations and supply chain areas. The chapter goes on to theoretically develop the research hypotheses pertaining to the mediated effect of asset visibility capabilities and sustainable competitive advantage (SCA). The hypotheses development concludes with a number of hypotheses for further empirical investigation. As final points, the chapter introduces the refined research model and a summary of the research hypotheses.

The remainder of the chapter is structured as follows; see figure 5-1. Section 5.2 discusses the pilot study findings concluding with the first hypothetical relationship. Section 5.3 provides a theoretical development of the second hypothetical relationship focusing on the mediated effect of asset visibility capabilities and SCA. Section 5.4 depicts the research model to be examined empirically and a summary of the research hypotheses. A summary of the chapter is introduced in section 5.5.

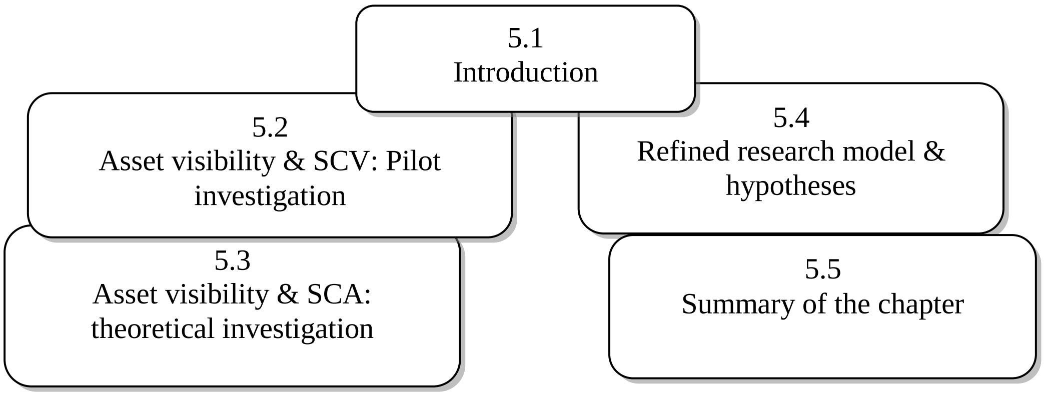


Figure 5-1: Structure of chapter five

5.2 Asset visibility on SCV and performance: Pilot investigation

The pilot study has explored the research questions relating to asset visibility capabilities that might influence SCV and performance. This section is informed by the initial conceptual framework provided in figure 5-2. As illustrated in this figure, two key capabilities were developed based on a review of the operations and supply chain management literature including technological and non-technological capabilities. The research has used these two major capabilities as "empty boxes" that were filled up through conducting the pilot study (Neuman, 2006). Based on analysis of the pilot data and the RBV concept, these capabilities have been reclassified into four capabilities incorporating the idea of core and complementary capabilities. The research now draws in turn on the factors constituting each of the four capabilities.

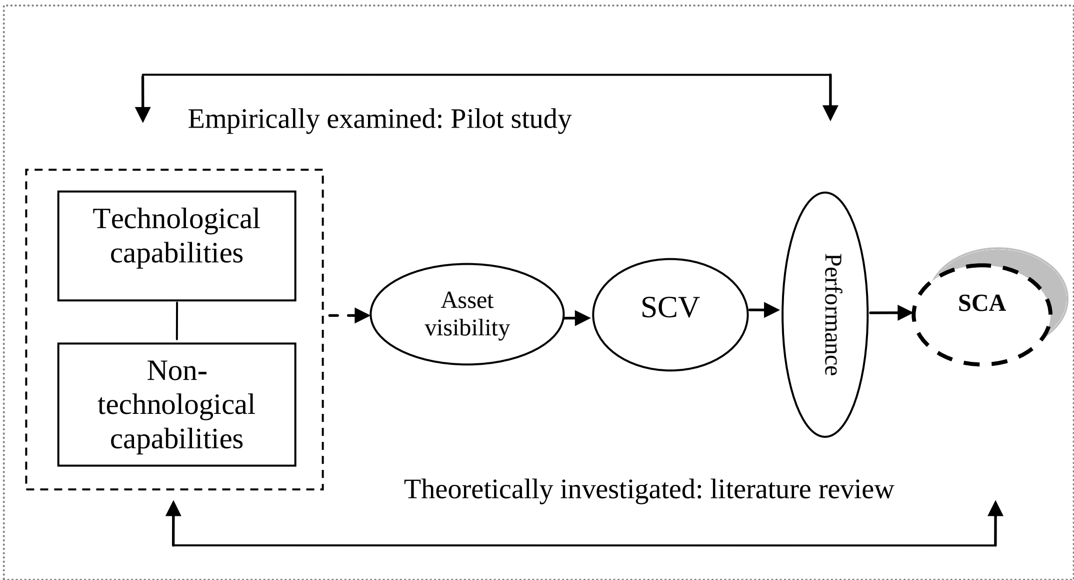


Figure 5-2: Conceptual model of asset visibility on SCV, performance, and SCV

5.2.1 Core technological capability: visibility and performance

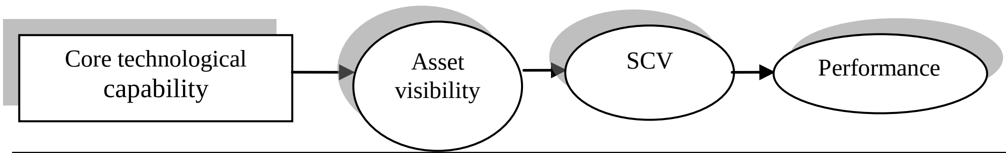


Figure 5-3: Core technological capability on SCV and performance

Core technological capability has been defined in this research as *the ability to manage technological resources that are directly related to asset visibility*. Here, technological resources are represented through the IT infrastructure for managing RTAs. In the pilot study, the RFID-RTAM system is used as an example of this IT infrastructure. The IT infrastructure for the RFID system includes mainly RFID passive or active tags containing a tiny chip, the RFID reader and its antenna to remotely interrogate the tag, and a middleware application as the link between the RFID application and the firm's applications (Glover & Bhatt, 2006). The research uses 'core technological capability of asset visibility' and 'asset management technological capability' interchangeably.

The pilot study has investigated the core technological capability of asset visibility and its effect on SCV and firm performance, see figure 5-3. The pilot study has revealed that the asset management technological capability appears to be formed by four principal sub-capabilities including the ability to (1) manage assets on an individual basis; (2) find the right assets; (3) know the current physical status of assets; and (4) keep historical records of these assets. These four capabilities are seen as good features for an asset management system that is driven by a unique electronic product code (EPC) (Lampe & Strassner, 2004). The asset visibility concept is primarily the ability to capture current information about the identity of an asset, its location and its physical status thus eliminating the gap between the planned and actual scheduled time of associated activities (Francis, 2008). RFID-RTAM systems are able to automatically and remotely track RTAs on individual basis. As such, RTAs can be located and identified without line of sight or human interaction. RFID-RTAM systems are also able to trace RTAs by keeping a historical record of each asset. Detailed information can be recorded on the RFID tag providing timely information about both RTAs and the items carried in them. Thus, the ability of a focal firm to track and trace RTAs throughout supply chains using automatic data capture technology represents the core technological capability of RTAs visibility.

This capability has been confirmed in much academic and practitioner work such as Kim, Tang, Kumara, Yee, and Tew (2008), Ngai, Cheng, Au, and Lai (2007a), Martines-Sala, Egea-Lόopes, Garcia-Sanches, and Garcia-Haro (2009), Attaran, (2007), Cannon and Reyes (2008), Johansson and Hellström (2007), Wilding and Delgado (2004), Aberdeen-Group (2004). The pilot study has proposed a positive relationship between the asset management technology capability that allows asset visibility, and better information sharing practices which ensure availability of updated and timely information. As such, asset management technological capability positively influences SCV.

The pilot study findings highlighted that asset visibility directly facilitates efficient logistics activities related to shipping, loading preparation, loading, unloading and put away activities. Better managing these activities has a positive effect on logistics performance (Kim et al., 2008; McFarlane & Sheffi, 2003). This in turn helps firms to better manage their resources, supply chain activities and relationships (Boeck & Wamba, 2008; Delen et al., 2007). Based on their case study research, Ngai, Cheng, Au, and Lai (2007a) reported that container depot companies using data capture technology reduced operating costs significantly through being able to better manage and locate their containers. The same study asserted that automated tracking and monitoring of these assets could diminish the cost of labour and maintenance. In addition, an asset management technology capability eliminates what the research called the *internal bullwhip effect* that is associated with variation in inventory and back-order levels due to poor visibility at an operational level rather than variation in customer demand which would be related to the *external bullwhip effect* (Kang & Gershwin, 2005; Raman, DeHoratius, & Ton, 2001). Eliminating the internal bullwhip effect based on better asset visibility and enhanced information sharing practices sustains efficient performance due to reducing operational costs (Heese, 2007; Moyaux, Chaib-draa, & D'Amours, 2007; Sari, 2010).

Based on the discussion of the core technological capability of asset visibility and the associated effect on SCV and performance informed by the pilot study findings and supported by the operations and supply chain literature it is hypothesised that:

H.1 *There is a positive relationship between asset management, as a core technological capability of asset visibility, and SCV.*

5.2.2 Complementary technological capability: Visibility and performance

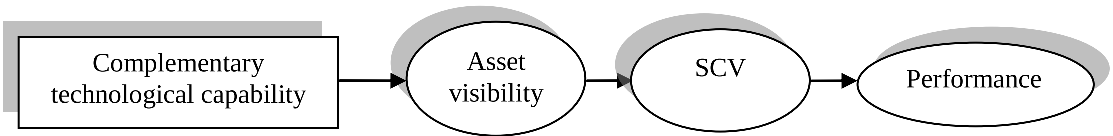


Figure 5-4: Complementary technological capability on SCV, and performance

This section discusses the pilot study findings in relation to the complementary technological capability associated with asset visibility and its impact on SCV and performance, see figure 5-4. Complementary technological capability has been defined in this research as *the ability to manage technological resources that are indirectly linked with asset visibility.* As the pilot study has indicated, the IT infrastructure for supply chain integration is a prerequisite for adopting automated asset management systems. The pilot study has confirmed that ICT is essential to communicate the throughput of automated RTAM systems as an input for other systems. Visibility is the main outcome of ICT systems that helps in facilitating internal collaboration between employees and external collaboration with supply chain partners. Besides, RTAM applications integrate with other supply chain applications such as planning and transaction applications for better visibility and performance. This communication and integration is a function of using a consistent language or format.

The RTAs data stored on RFID tags can only be beneficial if it is transmitted into a firm's information system in a readable and interpretable format (Kim et al., 2008). Data can therefore be exchanged and shared inside and outside a firm's boundaries. The IT infrastructure for supply chain integration consists of information communication technology (ICT) and collaborative supply chain applications. ICT (e.g. electronic data interchange EDI, web-based technology, electronic point of sale EPOS) facilitates communication and information exchange among supply chain actors. Hence, ICT plays a major role in communicating the throughput of tracking applications. Collaborative information systems and information technologies are significant in managing contemporary supply chains (Malhotra, Gosain, & El Sawy, 2005; Malhotra, Gosain, & El Sawy, 2007). Relying on the pilot findings, RFID-RTAM systems are seen as a collaborative supply chain system, its output is an input for other supply chain applications such as vendor-managed inventory (VMI), collaboration planning, forecasting and replenishment (CPFR), collaborative transportation management (CTM). An RFID application is seen as a facilitator for CPFR and as an supporter of smarter supply and demand chains (Pramatari, Doukidis, & Kourouthanassis, 2005). It is contended that firms that use supply chain collaborative applications such as VMI and CPRF are keener to adopt RFID (Sari, 2010). The pilot study has also shown that GPS as an example of a transport tracking application completes the missing link of achieving asset visibility during transportation journeys, and some studies have elaborated the benefits that can be gained from combining RFID with GPS (e.g. Baars, Kemper, Lasi, & Siegel, 2008). RFID if combined with GPS, can create an integrated tacking system that can be communicated through ICT and informs other collaborative supply chain applications.

The supply chain literature defined the IT infrastructure to integrate supply chain functions and activities as "*the degree to which a focal firm has established IT capabilities for the consistent and high-velocity transfer of supply chain-related information within and across its boundaries*" (Rai et al., 2006). Relying on this definition and informed by the pilot study findings, the complementary technological capability of asset visibility is represented through the IT infrastructure integration capability for supply chains.

According to Rai, et al. (2006), establishing the IT infrastructure for managing and integrating supply and logistics operations is not a capability unless it supports information sharing practices based on certain criteria including: (1) to support the use of data capture applications across the supply chain; (2) to ensure consistency in storing and presenting data; (3) to use common definitions for key data elements (e.g. customer, order, part number); and (4) to allow real-time communication between supply chain applications and planning and transactions applications. In her study, Angeles (2009) investigated the prerequisite IT infrastructure capability for supply chain integration that support the adoption of RFID. Her study relied in turn on the study by Rai, et al., (2006) in which they considered two key dimensions for IT infrastructure integration capability including *data consistency* and *cross-functional supply chain management application systems integration*.

Rai, et al. (2006) explained *data consistency* as the degree of consistency in defining and storing data. They contended that data architecture standards such as Extensible Markup Language (XML) and Structured Query Language (SQL) are increasingly being used for exchanging business data across inter-organisational systems (Van den Hoven, 2004).

RFID is an example of inter-organisational systems (Ngai et al., 2008). Data stored on RFID tags and read by an RFID reader transmitting through an antenna may be standard Electronic Product Codes (EPC) (Bottani, Montanari, & Volpi, 2010). RTAs data are then shared among authorised supply chain partners using the EPC global network as a type of internet technology, and then at each site, EPC Middleware is responsible for transforming EPC data into compatible and readable data (EPCglobal, 2004). As such, the data consistency of RTAM systems offers supply chain authorised partners near real-time information about RTAs during their forward and backward journeys throughout a supply chain (Bottani et al., 2010). Thus, data consistency in managing RTAs allows visibility at this level that can be communicated with other supply chain systems. This last point moves the research to the second dimension which is cross-functional supply chain management application integration systems.

Rai et al. (2006) and Malhotra et al. (2005) defined *cross-functional supply chain management application integration systems* as: the extent to which the functional SCM applications of a focal firm are able to communicate and interface in real-time with each other and with related Enterprise Resource Planning (ERP) and Customer Relationship Management CRM applications. ERP, SCM and CRM constitute enterprise systems (ES) that allow information integration (Hendricks, Singhal, & Stratman, 2007). Rai et al. (2006) differentiated between planning and execution applications. *Planning applications* are developed to replace traditional planning practices for effective functional planning relating to the warehousing, transportation, production and procurement functions. ERP allows automated standardised cross-functional transactions between different systems yielding reliable cross-functional supply chain information and in turn effective business plans (Hendricks et al., 2007; Kalakota & Robinson, 1999). *Execution applications* deal with the implementation of planned operational functions such as the distribution and logistics activities, inventory management practices, replenishment procedures and the order cycle management. SCM-related execution applications allow the capability to attain SCV and enhanced performance such as RFID, VMI, CRP and CPFR applications.

CRM applications aim at maintaining long-term relationships with customers through replacing inefficient practices with an automated sales, decision support, data warehousing, data mining and reporting tools (Hendricks et al., 2007). CRM systems help firms to eliminate data entry errors; keep historical records of customers; and centralise customer data when a firm deals with a variety of products (Hendricks et al., 2007).

Integration between supply chain applications, including automated asset management systems, leads to better information flow integration especially at an operational level. This facilitates co-ordination with internal firm processes, resulting in enhanced firm performance on different levels (Angeles, 2009; Hendricks et al., 2007; Rai et al., 2006).

As such, data consistency along with cross-functional supply chain management application integration systems constitute the IT infrastructure for supply chain integration as a complementary technological capability for asset visibility; to enhance SCV and in turn performance. Therefore, the research hypothesises the following relationship:

H.2 *There is a positive relationship between IT infrastructure for supply chain integration, as a complementary technological capability of asset visibility, and SCV.*

5.2.3 Core non-technological capability: visibility and performance

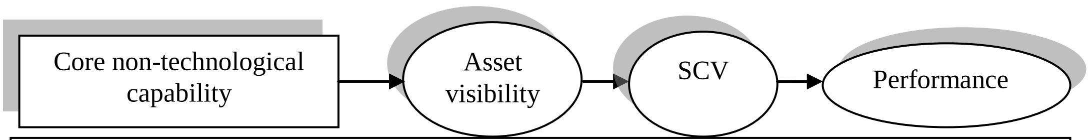


Figure 5-5: Core non-technological capability on SCV, and performance

This section discusses the pilot study findings related to the core non-technological capability associated with asset visibility and its impact on SCV and performance, see figure 5-5. Core non-technological capability has been defined in this research as *the ability to manage non-technological resources that are directly linked with asset visibility*. The pilot study findings concluded that the non-technological capability of asset visibility is mainly related to the transport logistics process including shipping, loading, unloading and put away activities. The pilot study has clarified that the capabilities shaping transport logistics process is associated with the extent to which a focal firm can (1) reduce delivery time of products as well as return time of empty RTAs, (2) eliminate errors of delivered products and returned RTAs, (3) efficiently manage firm's resources, and (4) provide accurate and updated information about logistics process. The pilot study data has illustrated how these non-technological capabilities of asset visibility are triggered by the technological capability and supported by distinct managerial practices. In turn, these are able to enhance SCV leading to better performance in terms of lower inventory levels, operational cost savings, on-time delivery, shorten order-to-fulfilment cycle time and increasing the frequency of orders.

According to Becker, et al. (2009) there are four specific effects of innovative data capture technology such as RFID, which appear to confirm the pilot study findings. These effects are associated with the process view and consider general IT capability. They include processing time reduction, error reduction, resource consumption reduction and process information. In this research, this capability is considered a process-related capability associated with the RFID-RTAM systems that can be used as indicators for asset visibility.

Process time reduction is the most common effect of RFID data capture technology associated with asset visibility. It is mainly related to automating the process in terms of avoiding human resources in data entry and data processing which is one of the general IT capabilities within Mooney, Gurbaxani, and Kraemer's (1996) model for assessing the business value of information technology. In considering managing returnable transport assets within the transport logistics process, barcode systems rely mainly on manual tasks offering several drawbacks such as the possibility of errors, longer task duration, various forms of waste and inefficient use of resources. These drawbacks are augmented when considering the current features of freight transport including cross-docking distribution centres through which stock is kept moving, shipments consolidation and flexible routing (Bhatnagar & Teo, 2009; Hesse & Rodrigue, 2004). The automating checking processes associated with load preparation, loading, unloading and put-away activities are therefore significant in minimising process time. This in turn shortens the lead-time of the associated supply chain operations including forward (product delivery) and backward (return of empty RTAs) logistics. It is proposed that the earliness of sharing information offered through RFID-RTAM system can enhance supply chain performance (Karaesmen, Buzacott, & Dallery, 2002).

Process error reduction is the second RFID-RTAM process-related capability associated with asset visibility. Error reduction is influenced by eliminating manual tasks (human interactions) that may incur errors. These errors refer to incorrect data capture, entry, or processing. RFID enables accuracy and correctness of data captured that minimises or even prevents any possibility of data errors. This capability is highly significant when considering the massive number of returnable transport assets travelling forward and backward across several links and nodes (Ngai et al., 2007a). Hence, RFID allows automatic scanning of these assets showing their current status and may keep a historical record of them. Furthermore, the process error reduction capability accompanied with RFID is critical in fulfilling customer orders i.e. easily locating the correct items or specific returnable transport assets that are engaged in further supply chain tasks or activities. These activities need to be performed correctly and on time to avoid any kind of supply chain disruptions and/or penalties and to improve customer satisfaction through on-time order delivery (Kim et al., 2008; Langer, Forman, Kekre, & Scheller-Wolf, 2007).

In considering *resource consumption reduction* as the third RFID-RTAM process-related capability associated with asset visibility, a firm's resources include materials in different forms, labour, tools and equipment. Visibility of assets through RFID systems allows better usage of a firm's resources by eliminating different forms of waste i.e. damage, theft, loss, misplacement and buffer stock. It also helps in improving inventory management, enhancing product quality and increasing asset utilisation through better maintenance practices (Ngai et al., 2007a). These reflect lower levels of resource consumption which is subsequently translated into operational cost savings and improved asset quality. RFID, through its automation capability, offers real time asset information that, in turn, allows asset visibility. This enhances the availability of RTAs across supply chain logistics activities by reducing the possibility of damage, theft, loss, misplacement and misuse. As a result, the number of RTAs that need to be replaced is substantially diminished. Furthermore, the quality of available returnable transport assets is improved through more efficient maintenance routines, which helps extend asset life cycle.

Process information is the fourth RFID-RTAM process-related capability associated with asset visibility. Improving process information is triggered by asset management technological capability related to timely capturing of electronic data that is transferred to the firm's information systems for processing and dissemination (Delen et al., 2007). The accuracy of real-time data captured improves the quality of process information offering better information transparency. An integrated tracking system (RFID with transport tracking applications such as GPS), offers the opportunity for updated and therefore timely information about transport journeys related to traffic delays or route changing that enhances information transparency and operational performance (Ergen, Akinci, & Sacks, 2007). This in turn enhances system responsiveness through more efficient and effective decision making processes, especially at an operational logistics level (Cheung, Choy, Lau, & Leung, 2008). Since returnable transport assets are associated mainly with transport logistics processes, using RFID offers electronic data capture that in turn allows accurate and real-time information for these assets across different stages of transport logistics process. Enhanced transport logistics information based on asset visibility thus influences SCV (Johansson & Hellström, 2007). It is contended that lateness of sharing information is one of key reasons for the bullwhip effect (Lee, Padmanabban, & Whang, 1997).

To conclude, RFID-RTAM process-related capability acts as the core non-technological capability of asset visibility and includes four key sub-capabilities: process time reduction, error reduction, resource consumption reduction and enhanced process information. These affect SCV and in turn performance. The research therefore hypothesises the following relationship:

H.3 *There is a positive relationship between process-related capability, as a core non-technological capability of asset visibility, and SCV.*

5.2.4 Complementary non-technological capability: visibility and performance

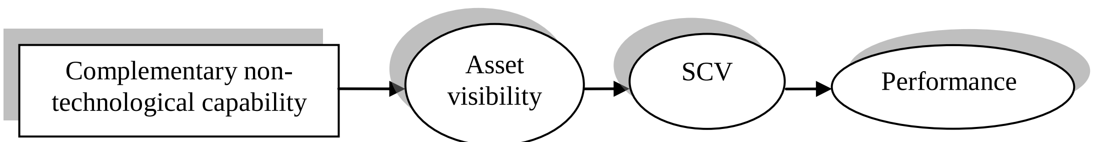


Figure 5-6: Complementary non-tech. capability on SCV, and performance

This section discusses the pilot study findings related to complementary non-technological capability associated with asset visibility and their impact on SCV and performance, see figure 5-6. Complementary non-technological capability has been defined in this research as *the ability to manage non-technological resources that are indirectly linked to asset visibility.* Over the last decade, supply chain management has become one of the major organisational practices as firms are electronically linked to their supply chain partners forming inter-organisational operations and relationships (Byrd & Davidson, 2003). Collaboration between supply chain partners may occur when "*two or more share the responsibility of exchanging common planning, management, execution, and performance measurement information"* (Anthony, 2000). Based on the pilot study findings, complementary non-technological capability has been classified into three categories: (1) supply chain process integration; (2) focal firm-3PL relational orientation; and (3) internal firm integration. The following sections discuss each of these capabilities, in turn.

5.2.4.1 Supply chain process integration: visibility and performance

The pilot study findings have confirmed that a firm's external integration in terms of supply chain process integration capability is associated with asset visibility and allows better SCV leading to better performance. Supply chain process integration is about information sharing between value chain partners as the crux of visibility. According to the pilot study data, three main dimensions constituting supply chain process integration capability have been extracted. These are physical flow integration, financial flow integration and information flow integration. These dimensions were confirmed by the relevant literature (Angeles, 2005; Malhotra et al., 2005; Rai et al., 2006). Supply chain process integration is defined as *the degree to which a focal firm has integrated the flow of information, physical materials, and financial information with its value chain trading partners* (Malhotra et al., 2005; Rai et al., 2006). Supply chain process integration requires a certain level of inter-firm relationships between supply chain trading partners supported by the IT infrastructure (Asif & Mandviwalla, 2005; Ellinger, 2000). The following sub-sections discuss the three dimensions of supply chain process integration.

Physical flow integration

Physical flow integration has been defined as *the degree to which a focal firm employs global optimisation with its value chain partners to better manage the downstream flow and the stock of material and finished products as well as the upstream flow of empty RTAs and returned products for repair or replacement* (Malhotra et al., 2005; Rai et al., 2006; Sahin & Robinson, 2002). It is argued that external integration is always able to enhance logistics performance and firm performance (Droge, Jayaram, & Vickery, 2004; Gimenez & Ventura, 2005). Although it has a crucial effect on supply chain disruption, almost all physical flow integration definitions have overlooked the upstream flow of empty RTAs. This study argues that upstream physical flow integration should consider the backward flow of empty RTAs that facilitates the availability of RTAs throughout the supply chain logistics activities. The availability of RTAs ensures continuous and streamlined flows of products.

The pilot study has indicated that physical flow integration is about sharing information regarding the actual progress of an order between a focal firm and its strategic supply chain partners (i.e. the physical flows of an order rather than financial flow). This includes sharing information about the progress of the shipping process from the shipper's firm to a destination firm or location and the return of empty RTAs to their supplier. Attaining integration and visibility at a physical flow level appears to be a gap in current supply chains due to ineffective asset management systems (Wittwer, Bittner, & Switzer, 2002). The pilot study has indicated that with manual asset management systems, the firm has almost no visibility of the physical flow of products. It is contended that IT capability has a significant influence on logistics capability and in turn firm performance in terms of responsiveness and flexibility (Zhao, Droge, & Stank, 2001). The pilot study along with the academic literature have confirmed the major role of automated data capture technology in driving information transparency at an operational level such as RFID-RTAM and transport tracking applications (Asif & Mandviwalla, 2005; Ergen et al., 2007; Schindler, 2003). This visibility allows better responsiveness and the flexibility that are essential for contemporary logistics systems (Bhatnagar & Teo, 2009; Hesse & Rodrigue, 2004).

To better manage physical flow integration capability, the literature has focused on enhancing inventory management practices. A number of techniques and programs have been adopted such as vendor-managed inventory (Disney & Towill, 2003), just-in-time deliveries (Zimmer, 2002), automatic replenishment (Myers, Daugherty, & Autry, 2000), outsourcing inventory management service (Van Hoek, 2000), and reconfiguring distribution network (Chopra, 2003; Cordeau, Pasin, & Solomon, 2006; Lemoine, 2004; lorentz, Wong, & Hilmola, 2007). This research contends that automated asset management systems represent another supply chain tool for improving inventory management practices throughout supply chains.

Physical flow integration as a complementary capability associated with asset visibility has a positive effects on firm performance through better SCV. This can be translated as follows: (1) operational costs savings associated with manufacturing, purchasing, warehousing and transport logistics activities; (2) enhancing lead time across supply chain especially for long delivery lead-times; (3) cutting buffer inventory and minimising stock outs as well as safety stock (stock keeping units); (4) eliminating waste and efficient resource management practices related to financial resources, human resources and physical resources e.g. shipping yards, transportation fleet, RTAs; (5) maintaining long-term relationships with value chain partners; and (6) improving customer satisfaction (Angeles, 2009; Asif & Mandviwalla, 2005; Ellinger, 2000; Gustin et al., 1995).

In this research, a number of indicators are used to evaluate physical flow integration including multi-echelon costs optimisation, joint management of inventory with logistics partners and suppliers, just-in-time deliveries and distribution network configuration for inventory optimal staging (Angeles, 2009; Elliot et al., 1999; Malhotra et al., 2005; Rai et al., 2006).

Financial flow integration

The pilot study has indicated that financial flow integration as a complementary non-technological capability of asset visibility influences SCV resulting in better firm performance.

Malhotra et al. (2005) and Rai et al. (2006) depict financial flow integration as *the extent to which financial resources exchanged between a focal firm and its trading partners in a supply chain are triggered by workflow events*. Although financial flow integration is the most common and earliest pattern of supply chain process integration, there is an inconsistent view among supply chain partners about their upstream and downstream financial flows (McCormack & Johnson, 2003). Supply chain financial flow integration has become of interest in the literature due to its influence on the entire supply chain performance in terms of reducing delays and enhancing productivity through eliminating redundant tasks (Marquez, Bianchi, & Gupta, 2004). It is argued that the lack of financial visibility in both downstream supply chain (e.g. invoices, credit terms, prices) and upstream supply chain (e.g. payments and account payables) is due to poorly designed business processes and a misperception associated with information disclosure as a loss of power or as a violation of privacy (Chan, 2009; Liu et al., 2005). Current e-business environments and inter-organisational systems support financial transparency and business process re-design (Malhotra et al., 2005; Marquez et al., 2004).

As the pilot study indicated, financial flow integration is associated with sharing information about the progress of the order process. This requires business process integration in the processing of accounts receivables and accounts payables. Financial flows concerned with accounts receivables help firms to estimate the average time between issuing a bill to a customer and collecting the payment. Financial flows of accounts payables allow the firm to estimate the average time between receiving the operational supplies (e.g. raw material), issuing the invoices by the supplier and paying the supplier. The firm can better manage financial flows based on the financial information available about the order cycle. This financial flow is enabled by event-based workflow systems allowing electronic payment upon delivery. E-business systems, specifically ERP, allow the integration of the two financial business processes related to the accounts payables of a buyer and accounts receivables of a supplier (Bowersox et al., 2002).

The pilot study findings have confirmed that asset visibility at an operational level is able to enhance financial flow integration through accelerating the financial order cycle time by relying on automated asset management systems. This allows near-real-time information about shipping and receiving activities, so that related bills and invoices can be executed faster. Financial flow integration as a complementary capability associated with asset visibility is able to improve SCV and firm performance. This can be translated in terms of the ability to reduce financial costs; accelerate order cycle time (invoicing, receivables); reduce financial errors and disputes; improve cash-to-cash cycle; improve customer satisfaction through better financial service; and enhance decision making process on different levels (Angeles, 2009; Greenfield, Patel, & Fenner, 2001; Rai et al., 2006) .

Information flow integration

Information flow integration is *the degree to which a focal firm shares operational, tactical, and strategic information with its supply chain partners* (Malhotra et al., 2005; Rai et al., 2006).

Physical and financial flows provide information sharing at an operational level related to the order process i.e. the actual flow of products and the associated financial transactions. It has been proposed that information sharing limited to the order level is not sufficient to guide and inform supply chain decisions, especially for upstream members related to their inventory and production processes; due to variation in orders levels and actual sales levels (Lee et al., 1997). Hence, sharing information related to demand information, sales and inventory levels, production and delivery schedules, and performance measures are significant in order to achieve better co-ordination at different levels. In considering enhancing co-ordination at an operational level, the pilot study findings have indicated that better asset management practices have resulted in enhancing sharing information about delivery schedules and inventory levels with major suppliers. It is argued that sharing stock keeping information can minimise supply chain inventory and in turn save costs (Gaonkar & Viswanadham, 2001; Klein et al., 2007; Lee et al., 1997). In addition, operational efficiencies can be improved by sharing delivery and production schedules (Gimenez & Ventura, 2005; Lee et al., 2000).

Moving from an operational to a tactical and then to the strategic level of co-ordination between supply chain partners involves higher maturity levels of inter-firm relationships. In relation to technological and non-technological capabilities, figure 5-7 depicts this research’s conception of a hierarchy of visibility in terms of the three visibility levels including operational, tactical and strategic. If all are achieved SCV might be attained. The maturity level of the inter-firm relationship is shaped by a higher level of mutual trust, aligning goals and a reliable history of the relationship (Lee et al., 2000; Lejeune & Yakova, 2005).

Sharing operational performance measures represents a tactical level of information sharing whilst sharing strategic information is related to information that becomes strategic when it is shared, due to its strategic value in optimising supply chain performance (Klein et al., 2007). Strategic information includes actual sales numbers that a focal firm shares with its supplier to enhance responsiveness, flexibility and in turn operational efficiency through enhanced supplier's demand planning, forecasting and replenishment activities (Klein et al., 2007; Lee et al., 2000; Lin et al., 2002).

The pilot study has provided support that asset visibility impacts on information flow integration at an operational level. This is the level that deals directly with the physical flow of products and associated financial processes that together influence operational performance, see figure 5-7. Operational visibility influencing operational performance is the initial step in attaining entire SCV that influences both tactical and strategic based visibility.

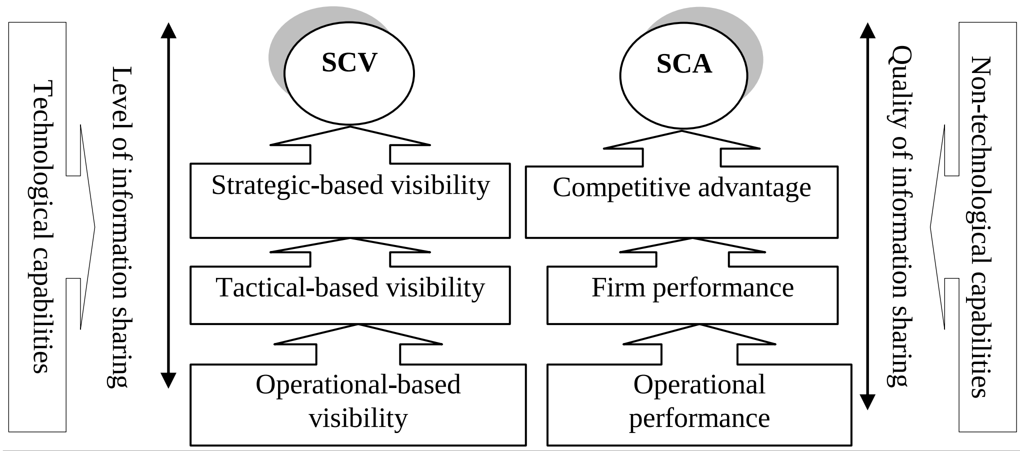


Figure 5-7: Hierarchical model of SCV and SCA

According to this research's discussion of supply chain process integration as a complementary capability of asset visibility that is considered the key mechanism for SCV and in turn performance, the research hypothesises that:

H.4a *There is a positive relationship between supply chain process integration, as a complementary non-technological capability of asset visibility, and SCV.*

5.2.4.2 Focal firm-3PL relational orientation: visibility and performance

The pilot study findings have highlighted the influential role of a focal firm's relationship with a third party logistics (3PL) relationship which is associated with asset visibility, SCV and performance. It is claimed that outsourcing logistics services has become the predominant pattern in current supply chains (Bhatnagar, Sohal, & Millen, 1999; Hertz & Alfredsson, 2003; Lai et al., 2008). Mentzer et al. (2001b) illustrate that downstream supply chains deal not only with customers but also with third party firms, such as 3PLs and 4PLs. The 3PLs perform logistics activities on behalf of manufacturers or focal firms. As such, 3PLs are responsible for managing the physical activities including warehousing, shipping, transportation and delivery (Halldorsson & Skjøtt-Larsen, 2004). 3PLs' services have extended to cover customer service, reverse logistics and after-sales help as value added activities (Jayaram & Tan, 2010). Asset management practices are managed mainly through the 3PL. As previously mentioned attaining physical flow integration requires a certain level of inter-firm relationships specifically between a focal firm and a 3PL (Halldorsson & Skjoett-Larsen, 2006).

The pilot study has indicated that improved SCV requires that value chain partners should work collaboratively, including 3PLs (Esper, Fugate, & Davis-Sramek, 2007). It is claimed that because transport logistics services are seen as a cost that should be eliminated, there is a lack of integration between a focal firm and 3PLs (Mortensen & Lemoine, 2008). Due to the pressure of enhancing delivery process as a competitive differentiator, better integration practices are in place with the 3PL who in turn seeks operational efficiency and customer satisfaction based on better service quality (Lai et al., 2008; Mortensen & Lemoine, 2008). It is contended that the 3PLs' role is significant in managing supply chain integration; this drives the incremental trend towards integration with 3PLs in recent years (Jayaram & Tan, 2010).

Although internal logistics integration is influential for enhanced firm performance especially for an in-house logistics system, external logistics integration has a significant impact on supply chain performance. The 'Arc of integration' concept refers to the scope of integration within and across firm's boundaries; narrower arcs refer to internal integration whilst wider arcs refer to external integration which is harder to attain (Frohlich & Westbrook, 2001).

External logistics integration is reflected by the extent to which the logistics activities of a buyer firm are integrated with the logistics activities of a 3PL and customers physically and virtually. Stock, Greis, and Kasarda (2000) refer to the main indicators for external logistics integration as follows: (1) the level of virtual and interpersonal logistics-related communication; (2) the level of co-ordination between logistics activities of the focal firm and logistics activities of its 3PLs and customers; and (3) the level of organisational distinction between the logistics activities of the focal firm and those of its 3PL and customers.

Internal organisational context and external supply chain context are the main factors affecting technology adoption in supply chains. Vaidyanathan (2005) maintains that 3PLs who use advanced IT applications are able to reduce logistics costs and attain supply chain integration thus enhancing visibility resulting in better productivity and higher growth. The same author asserts that significant IT improvements are expected to diminish transaction costs and help supply chain actors to manage increased complexity.

The pilot study has illustrated that innovative asset management systems such as RFID-RTAM systems are an example of supply chain collaborative technology that a 3PL can employ as inter-firm asset specificity. Asset specificity is defined as "*the degree to which a firm makes partner-specific investment in tangible physical resources, developing knowledge of partner procedures, culture, and technological know-how*" (Patnayakuni et al., 2006). The mechanism through which this asset is managed is reflected by the level of integration and collaboration between supply chain trading partners, specifically a 3PL and a focal firm. This mechanism can be demonstrated in terms of the level of mutual trust, aligning incentives, entity power and decision making, and information sharing (Lejeune & Yakova, 2005). The crux of this context is spanning the boundaries of firms linked in a supply chain. Hence, inter-organisational relationship capability is developed through certain relational interaction routines shaped through different forms and purposes of communication between a focal firm and a 3PL (Patnayakuni et al., 2006). Early adopters of RFID-RTAM (e.g. Wal-Mart, Metro, US DOD) have used their power to coerce their suppliers to use RFID systems. Recent study shows the positive impact of using this system on their suppliers stock returns (Deitz, Hansen, & Richey Jr, 2009).

3PL adoption of RFID-RTAM systems then creates asset specificity. These systems also have the capability to reshape the relationship mechanisms between the two parties to be more collaborative. The pilot study has indicated that a highly collaborative relationship between a 3PL and a focal firm might exist upon simultaneous adoption of the same technological standards (Wamba et al., 2008). This is conditioned by the length of a relationship, aligning objectives, mutual benefits and the size of a focal firm's logistics activities (Jayaram & Tan, 2010; Mortensen & Lemoine, 2008).

In their study, Jayaram and Tan (2010) proved that integration between a focal firm and a 3PL triggered by robust long-term relationships significantly and positively affects firm performance. Building on the idea of hierarchical visibility, different levels of integration influence different types of information sharing and visibility and might contribute toward better performance. Based on the pilot study findings and evidence within the literature, simultaneous adoption of RFID-RTAM supported by common ICT infrastructure allows integration between a focal firm and the 3PL on different levels. At an operational level, sharing information regarding the 3PL's delivery time schedules and a focal firm's order fulfilment process offers better SCV and in turn shortens lead-times and saves administration and operational costs (Mortensen & Lemoine, 2008). At a tactical level, sharing information on performance measures allows better co-ordination arrangements relating to delivery and replenishment processes. With respect to visibility at a strategic level, 3PLs might help a focal firm in making strategic decisions about entering new markets or adopting new technologies (Mortensen & Lemoine, 2008).

Based on the pilot study data, concerning the relationship between a focal firm's relational orientation with a 3PL as a complementary capability of asset visibility, SCV and firm performance, the research hypothesises that:

H.4b *There is a positive relationship between focal firm-3PL relational orientation, as a complementary non-technological capability of asset visibility, and SCV.*

5.2.4.3 Internal integration: visibility and performance

Drawing on the pilot study findings, internal firm integration can be seen to act as a complementary capability of asset visibility influencing SCV and in turn performance. This capability requires integration between business activities and functions for a smooth flow of materials and products to the end user (Harland, 1996). It is contended that the supply chain literature has paid a great deal of attention to integration between a focal firm and its supply chain trading partners. However, the literature has generally overlooked internal integration as a key link in attaining supply chain integration (Flynn et al., 2010; Gimenez & Ventura, 2005).

The pilot study findings have indicated that visibility associated with automated asset management practices requires better functional co-ordination and communications between different departments especially at an operational level. The main influencing capability of in-house logistics services under hierarchy structures is the extent of internal integration across firm's functional boundaries, that in turn influences the level of internal visibility. The results confirm a positive impact of internal visibility reflected by internal integration on SCV. Therefore, the success of a firm is partially based on internal departments' (including logistics) integration and value-adding processes for end customers (Morash & Clinton, 1997), termed here as integrated logistics (Stock et al., 2000). Based on a systems approach, integrated logistics involves the notion that a logistics system should be seen by the firm as a sub-system within the whole system that should not be optimised in isolation.

Internal cross-functional integration requires that logistics, manufacturing, procurement and sales are integrated and co-ordinated to gain customer value. In other words, a firm's functional boundaries should be removed and replaced by internal co-operation mechanisms to efficiently and effectively meet customer requirements (Flynn et al., 2010). The mechanism of this co-operation requires establishing a single central information system connecting all departments; cross functional teams to solve business problems; proper communication channels between departments; certain levels of co-ordination between logistics activities and other firm's activities; and certain levels of communication (electronic and/or personnel) between logistics and other departments (Braunscheidel & Suresh, 2009; Flynn et al., 2010; Stock et al., 2000).

The pilot study has highlighted the association between asset visibility and the adoption of innovative data capture technology. It is claimed that the use of cross-functional teams is significant for successful application and assimilation of a new information technology (Johnson et al., 2007). This requires interdepartmental information sharing and co-operation as critical factors for success.

As confirmed by the pilot study, the visibility of RTAs is an input for other firm's systems informing decision making process at different levels. This influences internal visibility and indirectly impacts on SCV. The pilot study results have elaborated the effect of internal integration practices as a capability associated with asset visibility on firm performance. This can be attained through better operational decisions in terms of saving operational costs, lead-time reduction, stock-out reduction and enhanced customer service (Flynn et al., 2010; Gimenez & Ventura, 2005; Van Hoek, 1998).

Based on the discussion of the pilot study findings related to internal firm integration as a complementary capability of asset visibility the research hypothesises that:

H.4c *There is a positive relationship between internal firm integration, as a complementary non-technological capability of asset visibility, and SCV.*

5.3 Asset visibility on SCA: Theoretical investigation

In this section, the research draws theoretically on the relationship between each of the capabilities associated with asset visibility and SCA that is followed by developing associated hypotheses. The research starts this section by providing an analytical/conceptual view of the creation of SCA. This initial understanding will then inform the hypotheses development process.

5.3.1 An analytical view on SCA

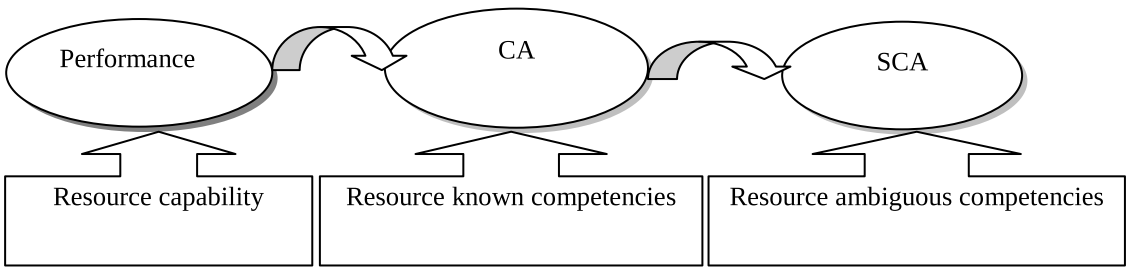


Figure 5-8: Formation of SCA

To understand the logic behind the creation of SCA, the research firstly clarifies the difference between the capability and competency concepts. The research defines '*capability*' as the ability to manage resources including physical, human and organisational assets, and '*competency*' as an above-average capability compared to firm's competitors or industry above-average performance (Barney, 1991; Barney &

Hesterly, 2006; Grant, 1991). The research argues that capability has a direct influence on performance whilst competency has a direct influence on competitive advantage. It has been argued that competitive advantage is often formed by organisational competencies that allow a firm to exploit the outcomes of its technological resources (Lengnick-Hall, 1992; Teece, 1986). On the other hand, dynamic capabilities indicate the capacity to continually renew competitive advantage (CA), especially in environments shaped by rapid technological change through (Teece et al., 1997).

A valuable non-technological capability can complement technological capability in a way that creates a co-operative competency which in turn influences competitive advantage (Barney, 1991; Dierickx & Cool, 1989). Relying on RBV, Tyler (2001) indicated that the above-average co-operative capabilities concept refers to competencies related to communication, information processing, knowledge transfer, internal and external coordination, and inter-firm relationship mechanisms (e.g. trust, goal congruence, and mutual goals). The author argued that above-average competencies that are formed through path dependency i.e. unique historical conditions are socially complex and ambiguous. These factors allow a firm to sustain and renew its competitive advantage (Teece et al., 1997). Hence, such above-average competencies are valuable, rare, inimitable, immobile and non-substitutable and become a source of SCA. Figure 5-8 depicts the transformation of enhanced performance based on resources' capabilities into SCA depending on the resources' competencies. The research now investigates the relationship between each aspect of asset visibility capabilities and SCA.

5.3.2 Core technological capability on SCA

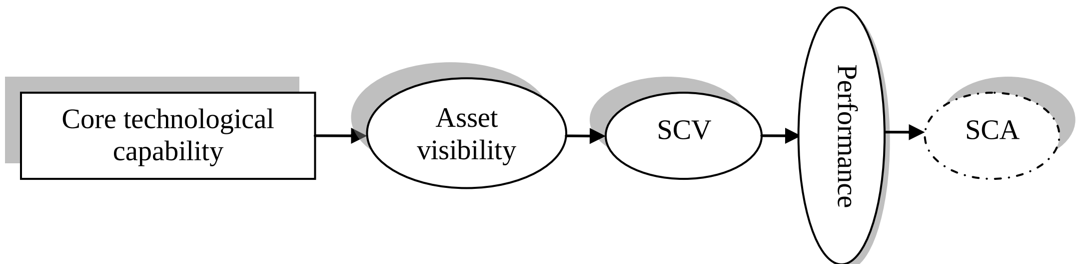


Figure 5-9: Core technological capability on SCA

In this section the research theoretically draws on the relationship between asset management technological capability and SCA, see figure 5-9. This section ends by developing the associated hypothesis for further empirical investigation.

Firms adopt innovative data capture technology such as RFID in order to streamline their supply chain operations that in turn results in finding new ways of attaining competitive advantage (Asif & Mandviwalla, 2005). Bowersox, Closs, and Cooper (2002) intimated that adopting state of the art IT differentiates a leading-edge 3PL from its peers. As a relatively new technology, the adoption of innovative asset management technology is constrained by the difficulties of quantifying the ROI, the complexity of the technology and the vagueness of first-mover advantages (Asif & Mandviwalla, 2005; Cannon et al., 2008; Dutta et al., 2007). The pilot study findings have indicated that the advantages of RFID-RTAM are seen in various areas of business processes, albeit these advantages are not always quantifiable. This might be a common concern with the adoption of most IT applications, that their outcomes are not measurable whilst firms are interested more in quantifiable ROI. However, a recent study conducted with the support of GS1 Italy (a global standard organisation that promotes EPC) suggested a positive ROI when RFID is used for RTAs (Miragliotta, Perego, & Tumino, 2009). IT applications' capabilities have a powerful influence on performance that might create competitive advantages through exceeding the industry average performance (Bhatt & Grover, 2005; McAfee & Brynjolfsson, 2008; Powell & Dent-Micallef, 1997; Tyler, 2001). It is contended that the strategic significance of RFID-RTAM is credible and innovative business values can be created through this system if it is integrated well with business processes (Tzeng, Chen, & Pai, 2008). Asset visibility is the main influence of automated asset management technology that triggers better operational decisions leading to better performance e.g. time and cost reductions. A direct link between asset management technological capability e.g. RFID-RTAM system and competitive advantage is difficult to prove due to the complementary effects of other factors that together influence competitive advantage (Powell & Dent-Micallef, 1997; Tyler, 2001).

As indicated in the previous section, a positive impact of this capability on SCV has been proven. This visibility informs business decisions on different levels (i.e. operational, tactical and strategic) resulting in enhanced firm performance in terms of reliable delivery, improved productivity levels and enhanced customer relationship. As such, the relationship between this technological capability and competitive advantage might exist if the transformation into a competency can be attained through the mediated effect of SCV and performance.

It is proposed that SCA can be created through an asset management technological capability. It is argued that the application of identical technology would not have the same outcomes for similar firms (Powell & Dent-Micallef, 1997). For example, the operating environment could be a barrier in recognising the potential benefits if the technology's requirements are not met. In considering an RFID-RTAM system, maintaining reading distances, elimination of collisions or interferences concern and tag protection are operational requirements (Glover & Bhatt, 2006; Wamba & Chatfield, 2009). The performance of the technology might also vary if inappropriate specifications are used for specific applications. With regard to data capture technology, specifically RFID-RTAM systems, each application is different. To find the optimal RFID solution to efficiently manage RTAs is based on technical and human skills whether internally based on IT business experience or externally through the IT solution provider. It is argued that IT yields superior rent by exploiting or leveraging complementary business resources that already exist (Clemons & Row, 1991). RFID-RTAM is a customised and joint solution, technical, human and managerial skills are developed through certain interaction routines over time constituting time compression diseconomies and are affected by social complexity factors. Early adopters of innovative asset management technology might create first-mover advantage through historical uniqueness (Barney, 1991; Barratt & Choi, 2007; Porter, 1985a). Hence, asset management technological capability is heterogeneously distributed between firms as they are formed through path dependency, causal ambiguity and social complexity. From an RBV perspective, asset management technological capability is valuable, rare, inimitable, immobile and non-substitutable. As such, asset management might be a source of SCA. Therefore, the research hypothesises the following relationship between asset management technological capability and SCA:

H.5 *There is a positive relationship between asset management, as a core technological capability of asset visibility, and SCA mediated by SCV and performance.*

5.3.3 Complementary technological capability on SCA

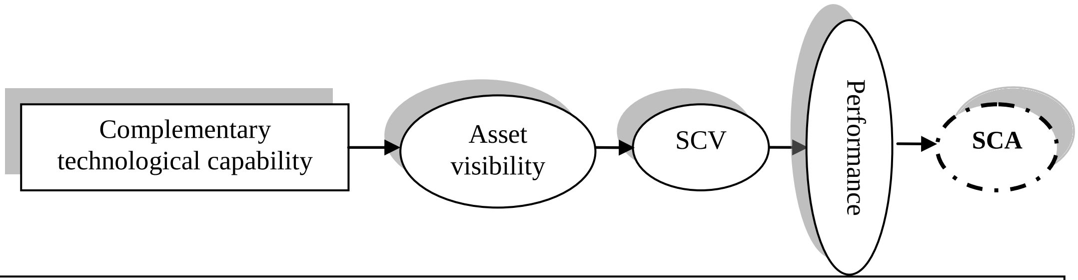


Figure 5-10: Complementary technological capability on SCV

This section draws theoretically on the relationship between IT infrastructure for supply chain integration as associated capability of asset visibility and their influence on SCA, see figure 5-10. This section ends by developing the associated hypothesis for further empirical investigation.

Supply chain integration driven by agile competencies is a vital tool for competitive advantage (Christopher, 2000; Yusuf et al., 2004). The key objectives of installing IT infrastructure for supply chain integration are attaining high levels of flexibility and responsiveness resulting in time reduction (Bhatnagar & Teo, 2009; Christopher, 2000). In terms of financial differentiation factors, an investigation of the effect of internet-based supply chain collaboration as an example of ICT on the determinants of competitive objectives has shown a positive impact on the amount of sales turnover and profit (Yusuf et al., 2004).

As previously mentioned, the direct relationship between IT capability and competitive advantage is widely debatable by both academics and practitioners. For example, Bhatt and Grover (2005) tested the relationship between quality of IT infrastructure and competitive advantage and found it non-significant. The authors suggested that IT infrastructure may not directly lead to differential competitiveness. The authors within the context of their study suggested that IT business experience and relationship infrastructure is more related to competitive advantage. Supporting the same logic, it is contended that enhanced competitive advantage requires integrating IT competency with other firm's competencies within business processes in a complementary mode (Clemons & Row, 1991; Powell & Dent-Micallef, 1997; Yusuf et al., 2004). Following the same strand, the pilot study findings supported by literature have confirmed the positive association between IT infrastructure for supply integration as a prerequisite capability for asset visibility, SCV and firm performance. Hence, examining the relationship between IT infrastructure competency and competitive advantage is mediated by the effect of other complementary factors which in this research are SCV and performance that in turn reflect various resources' competencies.

With regard to the sustainability of competitive advantage, Powell and Dent-Micallef, (1997) indicated three factors that act as criteria for achieving SCA through IT capability. These are continuous adoption of innovative ITs; first-mover advantages; and embedding IT capability within organisational business processes based on the RBV complementarity logic. Of these factors, the latter is widely accepted as the most feasible for generating SCA through IT (Powell & Dent-Micallef, 1997; Tyler, 2001).

Aral and Weill (2007) have developed a theoretical model of IT resources, defined as a combination of specific IT assets and organisational IT capability. The latter implies various human, managerial and technical skills shaped through for example formal and informal training, as well as internal and external interaction business routines. These business skills and interaction routines are heterogeneously distributed between firms and among supply chains and are developed through path dependency and social complexity causing causal ambiguity. As such, IT infrastructure for supply chain integrations can be valuable, rare, inimitable, immobile and non-substitutable and may therefore be a source of SCA. The research therefore hypothesises the following relationship:

H.6 *There is a positive relationship between IT infrastructure for supply chain integration, as a complementary technological capability of asset visibility, and SCA mediated by SCV and firm performance.*

5.3.4 Core non-technological capability on SCA

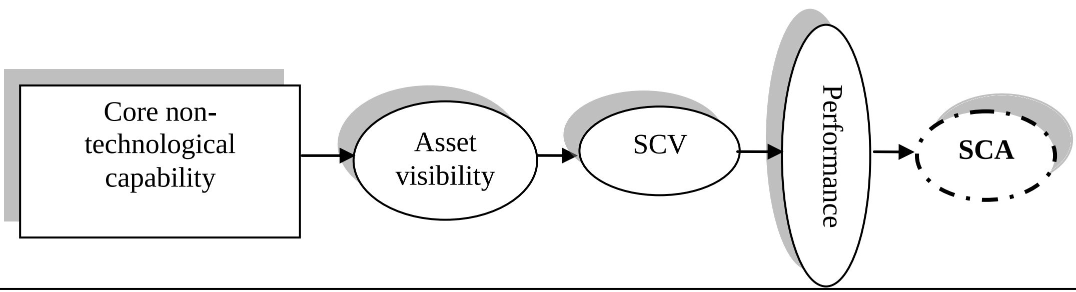


Figure 5-11: Core non-technological capability on SCA and performance

This section draws on theory about the relationship between process-related capability associated with asset visibility and their influence on SCA, see figure 5-11. This section ends by developing the associated hypothesis for further empirical investigation.

As illustrated from the previous section, process-related capability associated with asset visibility is mainly related to logistical processes. Within modern supply chains, there is a growing awareness that the delivery process has become a source of competitive differentiation as much as the product itself (Bhatnagar & Teo, 2009; Esper et al., 2007; Stalk, 1988).

The pilot study findings suggested the positive effect of this capability on SCV and firm performance through reliable delivery times; reducing return time of RTAs; eliminating delivery and return errors; efficient use of resources; and enhanced information process. This capability can be translated in the form of time reduction and cost savings. Lead-times reduction and dependable delivery are the key outcomes representing competitive determinants if the industry average is exceeded (Li et al., 2006a). In addition cost savings and better customer service at an operational level are seen as logistics competitiveness (Bowersox & Daugherty, 1995; Introna, 1991). Attaining the process-related capability associated with asset visibility might vary between firms and among supply chains creating different outcomes. This is due to different technological and organisational capabilities relationships with other systems such as barcode systems or even manual systems. In addition, uncertainty of demand and short lead-times have a negative impact on logistics capability and in turn on performance (Sari, 2010); this influences different levels of visibility and in turn performance.

As illustrated in figure 5-8, gaining competitive advantage requires a transformation of process-related capability into competencies that reflect competitive advantage. Porter (1985a) indicated the ways through which a firm’s key activities can create competitive advantage as a supplementary perspective for competitive advantage along with RBV (Spanos & Lioukas, 2001). Porter (1985a) clarified the characteristics of the firm’s activities in a value chain that might yield competitive advantage. Logistics as an activity to enhance competitive advantage is likely to share distinct economics, account for a substantial proportion of cost, and have a high level of potential effect on differentiation.

Logistics activities influence the performance of other activities within a value chain. This idea, known as 'linkages' is represented by Porter (1985a) who defined it as " *the way one value activity is performed and the cost of performance of another activity*". Linkages entail tradeoffs between activities to create the same overall outcomes. For example, to maintain the same level of customer responsiveness, poor visibility of SKUs results in ordering new stock which translates into a high cost base affecting the performance of other activities. Porter (1985a) explains two ways through which linkages can yield competitive advantage: *optimisation* and *co-ordination*. Hence, a firm needs to co-ordinate and optimise the linkages associated with logistics activities influencing its strategies to be able to gain competitive advantage. One way a firm can create value (based on a differentiation strategy) is to reconfigure its value chain.

Automated asset management systems allow better internal and external co-ordination practices especially at an operational level. With regard to capable and compatible IT and ICT infrastructure, asset visibility can ensure availability and accessibility of products leading to improved process-related capability in terms of time reduction, error reduction, waste reduction and enhanced information process. This in turn optimises overall SCV through better quality of shared information. Therefore, performance can also be optimised through enhanced responsiveness, flexibility and lower operational costs. A firm can achieve competitive advantage if this capability exceeds the average capabilities of its peers in terms of competency. Wal-Mart is a well-known example that could significantly increase sales, growth, market share and profitability compared to its rivals through co-ordinating and optimising logistics activities triggered by automated asset management system (Bhatnagar & Teo, 2009; Dutta et al., 2007).

The logistics competency associated with asset management technological competency, is also shaped by other organisational competencies. It is contended that maintaining a logistics competency is influenced by organisational learning mechanisms (Esper et al., 2007; Sandberg & Åman, 2010). With respect to Esper et al. (2007), organisational learning can be perceived through four components: (1) a cultural component encouraging an active unstructured learning environment through shared commitment and vision to learn within the firm and open-mindedness; (2) a structural component embedding learning within a firm as part of the organisational design offering a more flexible and decentralised learning environment but at the same time structured; (3) a relational component considering inter-firm learning mechanisms i.e. a firm and its supply chain partners can learn from each other based on aligning incentives and mutual trust; and (4) a temporal component referring to learning speed that is more influential in business environments characterised by rapid change and in which organisational learning becomes a dynamic capability. Hence, firms that are able to offer an organisational learning environment based on the four learning components are more likely to sustain competitive advantages related to their logistics competency. This competency is seen as valuable, rare, inimitable, immobile and non-substitutable resources. As such, the research hypothesises the following relationship:

H.7 *There is a positive relationship between process-related capability, as a core non-technological capability of asset visibility, and SCA mediated by SCV and firm performance.*

5.3.5 Complementary non-technological capability on SCA

This section discusses theory relating to the effect of complementary non-technological capability on SCA. This capability is represented through three sub-capabilities: supply chain process integration, 3PL relational orientation, and internal firm's integration. The following sub-sections elaborate these sub-capabilities in turn.

5.3.5.1 Supply chain process integration capability on SCA

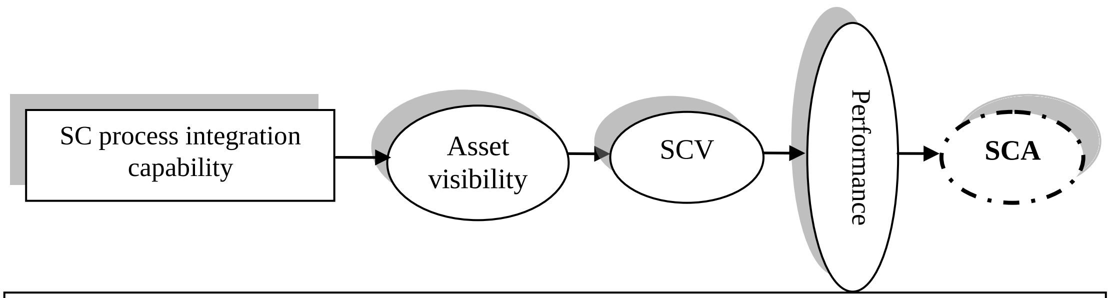


Figure 5-12: Supply chain process integration capability on SCA

This section draws a theory that addresses the relationship between the supply chain process integration capability associated with asset visibility and its influence on SCA, see figure 5-12. This section concludes by developing the associated hypothesis for further empirical investigation.

Supply chain process integration is mainly driven by IT applications as a key facilitator. Drawing on the research's view about hierarchical visibility illustrated in the figure 5-8, it is argued that the integration level of IT systems within a firm's strategy can reflect the firm's competitive position (Lucas & Turner, 1982). Three levels of such integration are considered.

First, independent IT systems might enhance operational performance based on operational visibility informing operational decisions. This is the case when innovative asset management applications are implemented for a specific process (e.g. RTAM, JIT manufacturing systems, inventory management, or distribution centre processes) to diminish the deficiencies of other systems such as barcodes or manual systems (Chuang & Shaw, 2007; Fontanella, 2004). In considering this functional integration, technological complexity, risks and the benefits related to RFID system are reduced. Here, the capability of an IT asset management system e.g. RFID, is more at an operational level offering better visibility, so that its impact is likely to be on operational performance.

The second level of integration between IT applications and firm's overall strategy is found when policies support IT systems can improve firm performance through visibility at a tactical level. This offers better assimilation of problem dynamics for better strategic planning and tactical decisions (Lucas & Turner, 1982). Under this situation, innovative asset management systems are adopted as an enabler for optimising intra-organisational practices among two or more business units within a firm e.g. manufacturing, distribution centres, or warehouses (Fontanella, 2004). According to this scenario, technological complexity, risks, managerial, organisational and human skills, and benefits related to RFID system are higher than in the previous situation (Chuang & Shaw, 2007; Wamba & Chatfield, 2009). Here, the influence of the innovative asset management adoption is more on firm performance as it is transformed from an operational capability into the firm's capability offering better firm's visibility.

Fully integrated IT systems within a firm's strategy may lead to gaining competitive differentiation through better visibility-based strategy that informs strategic decisions. This level of integration allows the adoption of innovative asset management systems at an inter-organisational level considering a limited number of trading partners e.g. first tier supply chain partners to better manage supply chain operations through better visibility (Chuang & Shaw, 2007; Fontanella, 2004). This inter-firm integration in turn enhances focal firm's performance as well as supply chain integrated partner's performance.

RFID as an example of innovative asset management systems represents an inter-organisational system that is able to enhance the integration of supply chain business process leading to better visibility and performance (Bose & Pal, 2005; Lee & Park, 2008; Ngai et al., 2008; Srivastava, 2004; Wamba et al., 2008). No doubt, technological complexity, risks, various internal and external skills and benefits related to RFID system are much higher within this pattern of integration. Therefore, simultaneous adoption strategy driven by aligning goals and mutual benefits for all supply chain partners is required (Chuang & Shaw, 2007). Variation in performance among supply chains is expected offering those with above-average performance level a competitive position. This research claims that supply chain process integration is a competency associated with automated asset management systems e.g. RFID-RTAM. This competency can be obtained if this system is integrated within the firm's strategy at more tactical and strategic levels, so that it can be a source of competitive advantage.

Although the integration model provided by Lucas and Turner (1982) was limited to the three levels, this research suggests another level of integration that amplifies the scope of integrated entities in a way that considers integration between supply chain wide strategy and inter-organisational technologies (IOSs). This level might be attainable sooner or later in certain supply chains considering the proliferation of innovative IOS and ubiquitous technology along with incremental awareness towards the significance of inter-firm relationships (New, 2010). Fontanella (2004) referred to the wide use of RFID application across a whole industry based on adopting common standards of the technology that might offer new forms of competitive advantage relying on above-average supply chain performance. With respect to a simulation-based study, Sari (2010) concluded that integrating RFID systems within a supply chain can yield substantial benefits conditional to high collaboration levels among trading partners. Bhatt and Grover (2005) also indicated the positive association between relationship infrastructure and competitive advantage.

In considering RBV, Tyler (2001) illustrated that maintaining the supply chain process integration competency requires integration between innovative asset management systems such as RFID-RTAM as technological competency and intra/inter-firm relationships as a co-operative competency. Adegbesan (2009) argued that complementarity of resources can create a surplus that exceeds the total values of each individual resource. The greater the degree of complementarity, the larger the surplus created (Adegbesan, 2009). With regard to a relational view, this competency is based on relational asset specificity and exploited over long periods through relational interaction routines between supply chain trading partners (Dyer & Singh, 1998). This competency is heterogeneously distributed between firms and among supply chains, so that they are valuable, rare, inimitable, immobile and non-substitutable resources. Therefore, supply chain process integration can be a source of SCA. As such, the research proposes the following hypothesis:

H.8a *There is a positive relationship between supply chain process integration, as a complementary non-technological capability of asset visibility, and SCA mediated by SCV and firm performance.*

5.3.5.2 Focal firm-3PL relational orientation capability on SCA

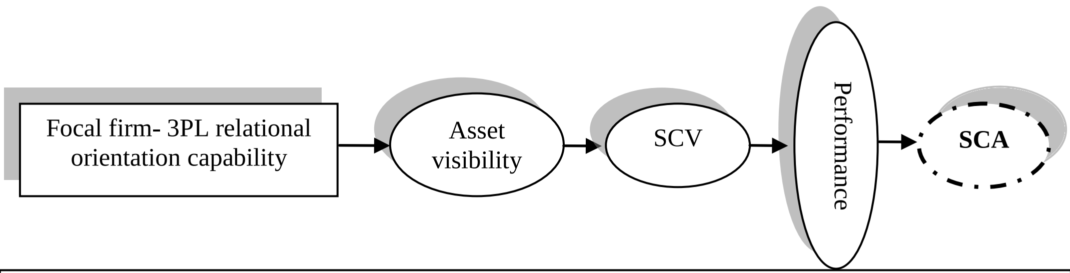


Figure 5-13: Focal firm-3PL relationship on SCA

This section examines theory relating to the relationship between the relational orientation with 3PL capability associated with asset visibility and its influence on SCA, see figure 5-13. This section concludes by developing the associated hypothesis for further empirical investigation.

As previously discussed based on indications from the pilot study, a positive relationship has been proposed between a focal firm's relational orientation with its 3PL as a capability associated with asset visibility and SCV, and performance. The crux of integration is information sharing and its outcome is visibility which informs business decisions for better performance (Bartlett, Julien, & Baines, 2007; Lamming, Caldwell, & Phillips, 2006; Rai et al., 2006). In considering a focal firm's perspective, internal logistics integration is influential for enhanced firm performance especially for in-house logistics patterns representing a hierarchical governance structure as well as external logistics integration that has a significant impact on supply chain performance (Fabbe-Costes, Jahre, & Roussat, 2009; Flynn et al., 2010; Frohlich & Westbrook, 2001).

The integration level between a focal firm and a 3PL is a dyadic relationship that varies and is reflected by formal (contractual) and informal relationships. With respect to the network approach, inter-organisational dynamics consider both types i.e. formal and informal mechanisms. The latter may have a stronger impact on the relationship governance than contractual mechanisms (Halldorsson & Skjoett-Larsen, 2006). It is argued that developing relational interaction routines, relational asset specificity and long term orientation are important inter-firm dynamics that facilitate mutual performance benefits and the development of competencies (Dyer & Singh, 1998; Patnayakuni et al., 2006). These mechanisms are also shaped by formal contracts driven by a network perspective rather than transaction cost theory or agency perspective. Both transaction cost theory and agency perspective focus only on incentives and contract types**;** are designed to mitigate goal divergence and to avoid relationship failure due to the risk of business uncertainty (Halldorsson & Skjoett-Larsen, 2006). Within the transaction cost theory, asset specific investment and other commitments are employed as functional replacements for trust to avoid opportunistic behaviour (Williamson, 1996). With respect to the network approach, mutual trust based on long term orientation is the appropriate mechanism to avoid uncertainty in business transactions. Halldorsson and Skjoett-Larsen (2006) contended that the nature of contracts as well as the inter-firm relational mechanisms may vary during the development of a relationship.

The literature shows some consensus that integration between a focal firm and a 3PL supported by a robust long-term relationship along with information integration significantly reduces transaction costs and positively affects firm performance (Dyer & Chu, 2003; Jayaram & Tan, 2010). This relational orientation capability is developed over time (Halldorsson & Skjoett-Larsen, 2006), so that the transformation into competency based on exceeding the average performance of a focal firm's rivals may accrue competitive advantage (Jap, 2001).

In their work adopting the 3PL perspective and focusing on enhancing customer/shipper's logistics performance based on 3PL customer orientation, Tian, Ellinger, and Chen (2010) argued that explicit value-creating behaviour should be implemented including leveraging logistics operations capability to positively influence shipper firm performance and competitiveness. In the same study, the authors concluded that 3PL customer orientation consists of four elements: service variety, timeliness, information availability and continuous improvement, which together significantly and positively predict focal firm logistics performance (Tian et al., 2010).

Improving current asset management systems represents an opportunity for better integration and co-operation between a focal firm and its 3PL. It is contended that customised and joint solution logistics represent the most influential levels of integration in such a dyadic relationship through which mutual benefits can be attained in terms of enhanced performance that might exceed the industry average (Halldorsson & Skjøtt-Larsen, 2004). With regard to a buyer-seller relationship, it is claimed that joint competitive advantage might be attained and maintained through specialised bilateral investment, goal congruence and reciprocal trust (Jap, 2001). Here, logistics partners need to negotiate how bilateral investment will be managed e.g. resources for IT customisation, whilst maintaining co-operative relationships through which strategic information are shared, yielding greater performance gains (Klein et al., 2007). Innovative asset management systems are examples of customised and joint logistics solutions that span the firm's boundaries representing inter-firm resources. Here the 3PL can help a focal firm to learn about new systems such as RFID-RTAM to generate reciprocal benefits (Wamba & Chatfield, 2009).

In considering the proliferation of ICT and IOSs, Powell and Dent-Micallef (1997) indicated that supplier relationships, including supplier logistics, is one of the six potential complementary business resources associated with IT; albeit, the expected outcomes of such IT systems are less if mutual trust and collaboration mechanisms are not established. Hence, establishing these mechanisms, building trust and making the relationship with a 3PL economically viable, maximises the benefits of employing innovative IOS (Powell & Dent-Micallef, 1997). With respect to ERBV, relational orientation capability that is translated in terms of relational interaction routines, relational asset specificity and long term orientation are able to create and maintain competency. This competency is heterogeneously distributed between firms and among supply chains, as such they are source of SCA (Dyer & Singh, 1998; Jap, 2001; Lewis et al., 2010). Thus, the research posits the following relationship:

H.8b *There is a positive relationship between focal firm-3PL relational orientation, as a complementary non-technological capability of asset visibility, and SCA mediated by SCV and firm performance.*

5.3.5.3 Internal firm's integration on SCA

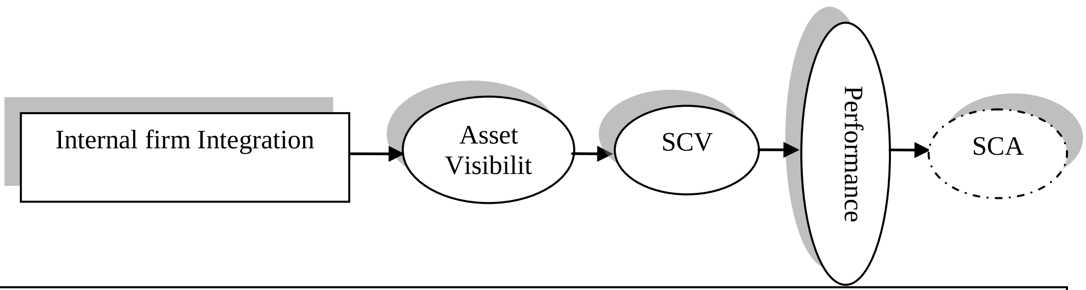


Figure 5-14: Internal firm integration competency on SCA

In this section the research draws on theory regarding the relationship between internal firm integration competency and SCA, see figure 5-14. This section ends by developing the associated hypothesis for further empirical investigation.

Supply chain integration is defined as "*the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra and inter organisation processes"* (Flynn et al., 2010). Three dimensions express supply chain integration: customer and supplier integration representing external integration along with internal integration. Internal firm integration is an integral part of supply chain integration that has been largely overlooked in supply chain literature due to intensive interest in external integration (Flynn et al., 2010).

The key objective of a focal firm's internal integration is that functions and departments should act as an integrated process in order to meet its customer's needs. It is contended that internal integration is significant for maximising supply chain value (Flynn et al., 2010; Frohlich & Westbrook, 2001). The pilot study findings supported by literature show a positive relationship between internal firm integration as a complementary capability of asset visibility, SCVand in turn performance. Gimenez and Ventura (2005) argued that internal integration influences external integration, so that internal integration is able to improve performance measures even with the absence of external integration. In other words, internal integration can be treated as a prerequisite for external integration. In their study, Droge et al. (2004) contended that internal integration positively predicts time-based performance and in turn firm performance. Inspired by Lucas and Turner's model of the integration between firm's overall strategy and IT systems (1982), asset visibility is proposed to enhance internal integration especially at an operational level resulting in operational-based visibility and in turn enhanced operational performance. The expected outcome here might vary based on the type of logistics service i.e. in-house vs. outsourcing. Internal integration at a more tactical and strategic level means that improved firm's visibility and performance might lead to gaining a competitive position if this integration is linked to a firm's supply chain integration. As suggested by the pilot study and echoed in the literature, innovative asset management systems such as RFID have the capability to enhance internal integration (Singh, Kee-hung, & Chen, 2007). It is claimed that every firm has its own context-specific requirements, so that adopting innovative asset management systems requires the alignment between the capability of the technology and relevant organisational policies and practices, as a prerequisite before being extended to the inter-firm supply chain level (Singh et al., 2007).

With reference to the transformation logic of SCA, attaining competitive advantage through internal integration capability requires a transformation of this capability into a competency. This competency expresses above-average performance against a firm's competitors. The original version of RBV focuses on creating competitive advantage based on firm's bounded resources and capabilities (Lewis et al., 2010; Mesquita, Anand, & Brush, 2008). Although the context of internal integration seems to be a typical example of this original RBV logic, this is not the case when considering internal and external integration in supply chain management. It is contended that internal integration is the basis of supply chain integration and informed by external integration (Flynn et al., 2010). To put it another way, information sharing is the crux of integration and allows different types of information to span firms' boundaries influencing various levels of visibility e.g. operational, tactical, or strategic. Internal integration competency requires maintaining both intra-firm and inter-firm mechanisms in terms of internal and external reciprocal trust and goal congruence supported by long-term orientation. With respect to sustaining internal integration competency, social complexity and path dependency of this competency is shaped through various business and team skills and internal/external interactions routines resulting in ambiguity of causality. Hence, this competency is valuable, rare, inimitable and non-substitutable. Therefore, they are source of SCA. Thus, the research hypothesises the following relationship:

H.8c *There is a positive relationship between internal firm integration, as a complementary non-technological capability of asset visibility, and SCA mediated by SCV and firm performance.*

5.4 The refined research model and a summary of the hypotheses

This section shows the refined research model and provides a summary of the hypotheses.

5.4.1 The research model

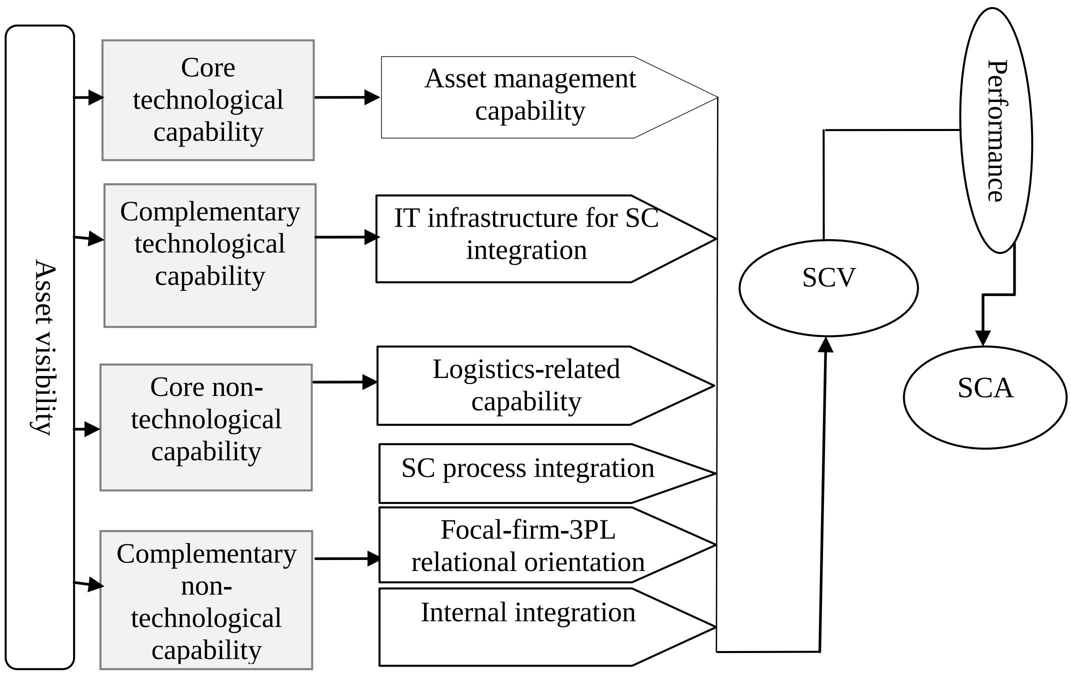


Figure 5-15: Refined model of asset visibility on SCV, performance, and SCA

The pilot study investigated the initial model illustrated in figure 5-2, which focused on exploring the main capabilities associated with asset visibility and their effect on SCV and firm performance. Detailed discussion of the pilot study findings supported by relevant literature has led to a refined model and six hypotheses have been developed. Theoretically, the research has expanded the relationships to cover the effect of asset visibility capabilities on SCA; as such, another six hypotheses have been posited.

The refined model, adopting an ERBV perspective, considers capabilities, which can be seen as either core or complementary. Core capabilities are those that have a direct impact on attaining asset visibility and include the associated asset management technological capability as well as logistics capability. On the other hand, complementary capabilities are those that have an indirect effect on asset visibility and relate to IT infrastructure for supply chain integration, supply chain process integration, focal firm-3PL relational orientation and internal firm integration. There are four types of supply chain capabilities that may enhance visibility through asset visibility: core technological, core non-technological, complementary technological and complementary non-technological. The study considers this classification when developing its empirical model; figure 5-15 depicts the refined research model for further empirical investigation.

5.4.2 Summary of the research hypotheses

Figure 5-16 provides a summary of the research hypotheses including two hypothesised relationships as follows:

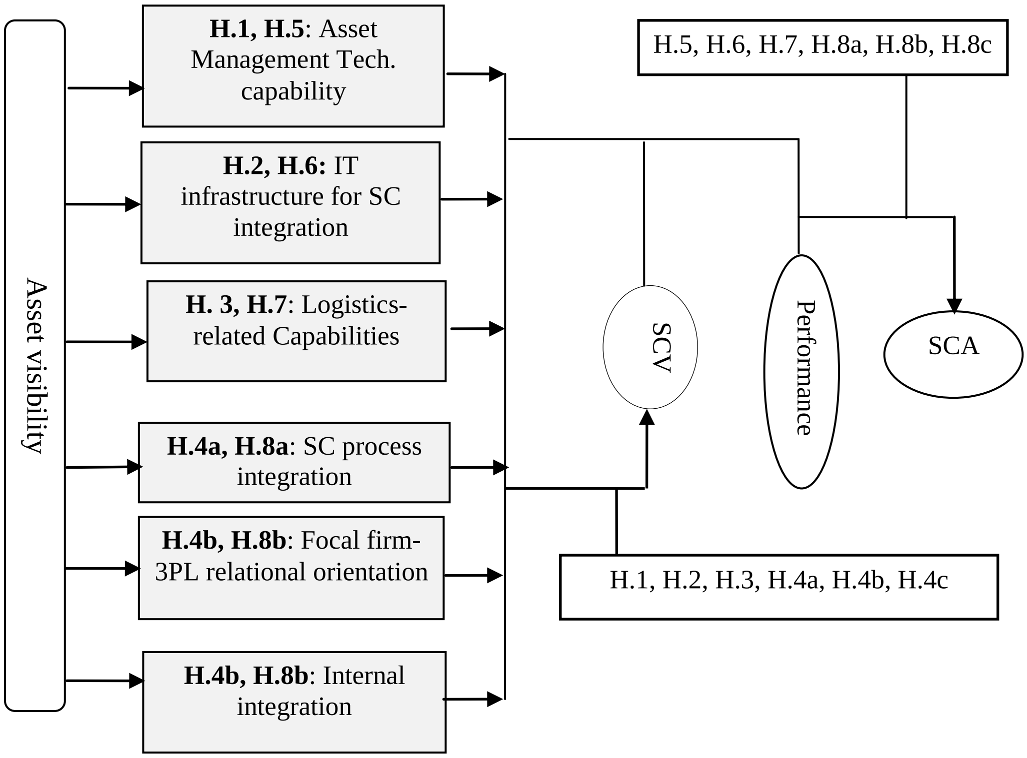


Figure 5-16: Research hypotheses

The effect of asset visibility capabilities and SCV

Six hypotheses were developed expressing the hypothesised relationship between asset visibility and SCV.

H.1 There is a positive relationship between asset management, as a core technological capability of asset visibility, and SCV;

H.2 There is a positive relationship between IT infrastructure for supply chain integration, as a complementary technological capability of asset visibility, and SCV;

H.3 There is a positive relationship between process-related capability, as a core non-technological capability of asset visibility, and SCV;

H.4a There is a positive relationship between supply chain process integration, as a complementary non-technological capability of asset visibility, and SCV;

H.4b There is a positive relationship between focal firm-3PL relational orientation, as a complementary non-technological capability of asset visibility, and SCV;

H.4c There is a positive relationship between internal firm integration, as a complementary non-technological capability of asset visibility, and SCV.

The mediated effect of asset visibility on SCA

The mediated effect of asset visibility on SCA is represented through six hypotheses as follows:

H.5 There is a positive relationship between asset management, as a core technological capability of asset visibility, and SCA mediated by SCV and firm performance;

H.6 There is a positive relationship between IT infrastructure for supply chain integration, as a complementary technological capability of asset visibility, and SCA mediated by SCV and firm performance;

H.7 There is a positive relationship between process-related capability, as a core non-technological capability of asset visibility, and SCA mediated by SCV and firm performance;

H.8a There is a positive relationship between supply chain process integration, as a complementary non-technological capability of asset visibility, and SCA mediated by SCV and firm performance;

H.8b There is a positive relationship between focal firm-3PL relational orientation, as a complementary non-technological capability of asset visibility, and SCA mediated by SCV and firm performance;

H.8c There is a positive relationship between internal firm integration, as a complementary non-technological capability of asset visibility, and SCA mediated by SCV and firm performance.

5.5 Summary of the chapter

This chapter has aimed at discussing the key findings associated with the empirical qualitative investigation of the research's initial conceptual model and then to theoretically extend this discussion to develop hypotheses. Therefore, this chapter has provided a detailed discussion of the pilot study findings that led to developing the hypothetical relationship pertaining with the effect of asset visibility capabilities including four key capabilities core technological; non-technological; complementary technological; and non-technological on SCV. This was followed by a theoretical investigation into the impact of these capabilities on SCA. The chapter concluded with the research model and a summary of its associated hypotheses for empirical quantitative examination that will be presented in the following chapter.

Chapter 6: Quantitative analysis

6.1 *Introduction*

The key purpose of this chapter is to investigate the survey data through appropriate quantitative techniques. To this end, the chapter starts with a brief description of the data entry process and a detailed examination of the appropriateness of the data before launching any analysis. This entails employing suitable techniques for checking the significance of missing data and outliers. Secondly, exploratory factor analysis is conducted to create the construct measures for of this research. The quality of developed scales and measures are examined to ensure validity and reliability. Finally, the research hypotheses constituting the proposed model are tested using appropriate techniques including standard multiple regression and bootstrap multiple mediation.

The remainder of the chapter is structured as follows; section 6.2 discusses the preliminary analysis for the purpose of data preparation. Section 6.3 focuses on developing the construct measures of the study using factor analysis. This is followed by section 6.4 that checks the quality of created scales. For the purpose of testing the proposed conceptual model, section 6.5 investigates the assumptions of regression model. This is followed by hypotheses testing in section 6.6. A summary of the chapter in section 6.7.

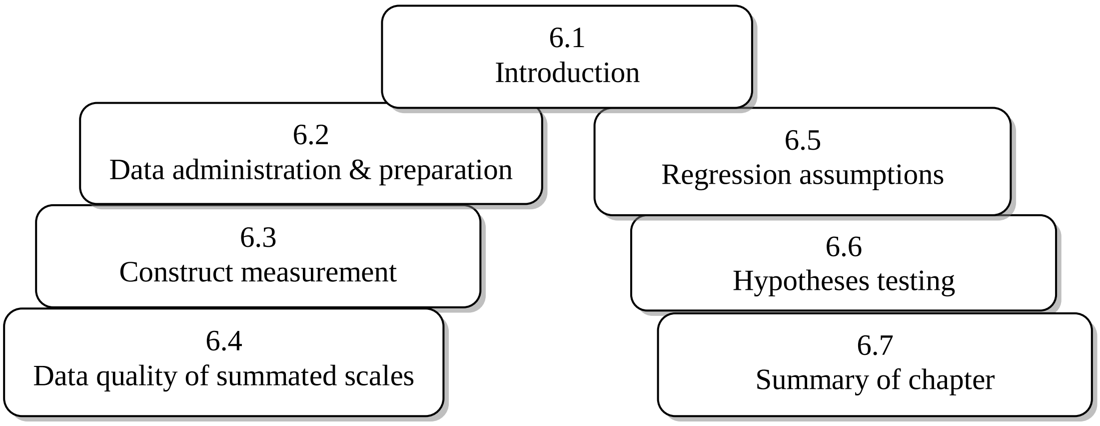


Figure 6-1: Structure of chapter six

6.2 Data administration and preparation

Compared to traditional mail surveys, electronic mail surveys (e-Mail survey) offer a number of advantages for operations management researchers, particularly higher response rate and better accuracy of data entry (Klassen & Jacobs, 2001). In this research, the average response time for completed surveys is 14 minutes. Data has been uploaded from the survey software (professional Survey Monkey) to an excel file in which the basic data cleaning has been done. This included coding variables and creating dummy variables for the control variables. The following step was transferring the excel data file into an SPSS file. The research has used the SPSS 17 statistical package. Prior to conducting any statistical analysis, reversing negatively worded items were considered for three variables (Bryman & Cramer, 2005, pp.52-55). In addition, the appropriateness of data set for the proposed statistical analysis has been checked using suitable techniques. The following sections examine the significance of missing data and outliers.

6.2.1 Missing data

Missing data, whether parametric or non-parametric, is a common problem in survey research as usually a large number of items and respondents are needed (Tsikriktsis, 2005). Missing data has a negative impact on statistical power i.e. the probability that a given test will find an effect assuming that it exists in the population (Field, 2005). It may also lead to biased estimates related to measures of central tendency, measures of dispersion, and correlation coefficient (Tsikriktsis, 2005). The following section examines the extent and patterns of missing data in this research.

Testing the amount and the pattern of missing data

There are no rigid guidelines for how much missing data can be tolerated for a sample of a given size (Tabachnick & Fidell, 2007, p. 63). Cohen and Cohen (1983) state that missing data on a certain variable of 5% or 10% is not considered large. Tabachnick and Fidell (2007) argue that the pattern of missing data is more important than the amount of missing data. Less serious problems are expected from missing values distributed randomly through a data set.

Prior to the analysis, 27 cases of a total of 129 cases have been excluded as they had more than 50% missing data, in most cases due to failure to complete the survey. Some data were missing because a number of questions were not applicable to certain participants. In this research, if the participant does not deal with 3PL the related questions were not applicable i.e. the questions associated with the measurement scale of focal firm-3PL relational orientation capability. The number of participants who do not deal with 3PL is 9 (calculated based on the survey results related to the type of logistics service) and the number of questions associated with this scale is 15 constituting approximately 25% of whole independent variables' questions. Hence, 135 (15 x 9) responses representing 2% of the whole responses were missing, yet this is justifiable. This is also confirmed through testing the pattern of missing data as no specific pattern was detected for these cases. All the analyses are based on the remaining 102 cases. Almost half of these cases have no missing data.

Diagnosing the randomness of missing data

There are three methods to diagnose the randomness of missing data including assessing univariate missing data using t-tests, dichotomised correlation to assess bivariate missing data, and testing the level of randomness of missing data. The research investigates the randomness of missing data relying on these methods.

First, assessing missing data for a single variable

This method is conducted by forming two groups of observations; one with valid data and the other one with missing data. An independent sample t-test is used to predict missing data from other variables in the data set (Tabachnick & Fidell, 2007, p.68). The vast majority of the cases have shown non-significant differences between the two groups of valid and missing values. Very few cases (only five) have significant differences, reflecting a random pattern (Hair, Anderson, Tatham, & Black, 1998, p.50). The missing pattern table, that shows cases with missing values, indicates that most of the missing data were due to respondents who failed to complete the survey. As such, no specific pattern of missing data appeared either within variables or cases.

Second, dichotomised correlation

The purpose of this technique is to assess the correlation of missing data for any pair of variables. Each valid variable value is represented by 1 whereas a missing value is represented by 0. The degree of correlation between these variables indicates the degree of randomness of missing data on each pair of variables (Hair et al., 1998). High correlations indicate non-randomness pattern of missing data in the variables pair and vice versa. Since there is no firm guidance identifying the level of correlation indicating that the missing data is not at random, the degree of randomness can be conservatively decided based on the statistical significance of the correlations test (Tsikriktsis, 2005).

Based on this method, and after excluding variables with less than 5% missing data, the results show low and non-significant correlations between most of the variables' pairs, indicating randomness of missing data .

Third, testing missing completely at random

Missing data can be missing completely at random (MCAR), missing at random (MAR), or missing not at random (NMAR) (Tabachnick & Fidell, 2007, p.62). MCAR is the best type of missing data as the distribution of missing data is unpredictable. As such, results relying on data from cases with complete data should be generalisable to those with missing data (Tsikriktsis, 2005). Little's MCAR test (Chi-square χ^2 = 1482.945, p = 1.000) indicated a desired statistically non-significant result confirming that the probability that the pattern of missing data violates randomness is greater than .05. i.e. missing data was missing completely at random (Tabachnick & Fidell, 2007). Therefore, in this research, the employed three methods confirmed the randomness of missing data. The following section investigates ways for treating both parametric and non-metric missing data.

Remedies for parametric missing data

There are two key approaches implemented through certain techniques for treating missing data including deletion approach using only valid cases (listwise option on SPSS) or all available cases (pairwise option on SPSS) and substitution approach based on mean substitution, regression imputation, or expectation maximisation (Tabachnick & Fidell, 2007).

Since the research endeavours to use regression models after conducting an exploratory factor analysis that both are based on inferential statistics, it is unlikely to use expectation maximisation method (EM) due to its associated biased results problem (Tabachnick 2007, pp.71-72). Besides, the regression imputation method requires highly correlated variables that allow good prediction for the missing data. Tabachnick and Fidell (2007, p.613) suggest that if data are missing in a non-random pattern or if sample size becomes too small, estimation is recommended. However, in this research the pattern of missing data are completely at random and the sample size is not very small, so the estimation option is excluded.

In this research, Listwise deletion was avoided as it eliminates a number of cases and substantially reduces the size of the data set (i.e. 54 cases instead of 102 cases) which in turn negatively affects statistical power. Pairwise deletion appears to be an appropriate technique to handle the missing data as it gives the most accurate results. This approach allows the use of all available information when calculating the correlations. However, it may show some inconsistencies in the calculated correlations due to variation in the number of observations used in the calculation. In the case of low reliability of multiple-item scales (i.e. Cronbach's coefficient alpha < .6), using pairwise option results in an unreliable scale (Tsikriktsis, 2005). In this research reliability values of multiple-item scales (this will be discussed later in details within data quality section) are relatively high, ranging from .813 to .945. Compared to Listwise deletion, Pairwise deletion gives more accurate estimates of population parameters e.g. correlations and regression weights (Tsikriktsis, 2005). This option is recommended if missing data are random and ranging from 10% to 20% (Hair et al., 2010; Tsikriktsis, 2005). In this research data are MCAR and missing data constitutes 13%. As such, the pairwise method is employed.

Remedies for non-parametric missing data

Unlike parametric variables, categorical or non-metric variables are typically not replaced by the imputation process. Hair et al. (1998) suggest two options; either using a specific modelling approach or leave missing data. In this research, for practical reasons, the latter option has been adopted.

6.2.2 Outliers

In considering univariate, bivariate, and multivariate statistics, an outlier is a score that is extremely different from the rest of the data (Field, 2005, p.74). In considering continuous variables, detecting outliers is based on whether data are grouped or ungrouped (Field, 2005). In Ungrouped data analysis using e.g. factor analysis, regression, and structural equation modeling, univariate and multivariate outliers are sought for all cases at once. However, for grouped data analysis using e.g. MANOVA, discriminant analysis, and logistic regression, outliers are detected separately within each group. This research is interested only in factor analysis and regression that are used for ungrouped data, so that outliers were simultaneously sought for all cases. The following sections examine, in turn univariate, bivariate, and multivariate outliers.

Identifying univariate outliers

Outliers have been checked through visual inspection using box-plots (box-whisker diagrams) and stem and leaf plots. 29 variables had outliers ranging from 1 to11 i.e. 4 outliers per variable in average. These 29 variables include 8 independent and 21 dependent variables out of 100 in total that, in turn includes 59 independent and 41 dependent variables. Outliers should be retained unless there is a clear proof that they do not represent any observations in the population (Hair et al., 1998, p.66). Hence, the following section investigates the significance of univariate outliers.

Checking the significance of univariate outliers

Two methods were applied to check the significance of the outliers; trimmed mean and Z-scores. The two methods were applied in turn.

(1) Trimmed mean

Trimmed mean as a statistical tool is used to measure the influence of outliers on mean. To calculate this value, the top and bottom 5% of the cases are removed and then a new mean value is recalculated (Pallant, 2007, p.59). If the values of two means are very different, this indicates a significant effect of outliers on the mean. In such a situation, further investigation is required, see (Field, 2005, pp.78-79). In this research, most outliers showed differences of less than .1 between the trimmed means and the arithmetic means that are ranged from 0 to .18 indicating non-significant influence of outliers on mean.

(2) Z-scores

Z-scores method is another technique for detecting univariate outliers that requires converting data to standard scores, with a mean of 0 and a standard deviation of 1. Most of the detected outliers showed non-significant influence on the mean. Almost all absolute values are less than 1.96 ($\alpha = .05$) except 25 values were more than 1.96 but less than 2.58 ($\alpha = .01$), which means there was no significant influence of the outliers on mean. Only 4 absolute values were more than 2.58 but less than 3.29. It is contended that no cases should exceeds 3.29 (Field, 2005, p.76). Besides, Tabachnick and Fidell (2007) claim that cases with values more than four should be investigated. As such no particular concern about the significance of detected outliers are raised. The next section provides a treatment for univariate outliers.

Remedies for univariate outliers

There are different options to reduce the effect of outlier's values. Field (2005) refers to three different techniques. The first one is to *delete the case*. However, this is not recommended unless there is a strong evidence that the case does not represent the targeted population. Since no outliers have been proved to be not from the population, this option was excluded.

The second option is *transformation of the data* that is applied if the distribution is not normal. Although absence of normality is not the case in this research (normality is investigated later within the assumptions of exploratory factor analysis), the researcher tried this option using natural logarithm (Log10) and square root (Sqrt). However, the transformed data resulted in more outliers compared to untransformed (original) data. Hence, this technique was rejected. The last option is to *change the score of outliers*. Field (2005) refers to three methods for replacing the score of outliers; (1) using the next highest score plus one, (2) converting back from a z-score and adding three times the standard deviation to the mean, (3) using the mean plus two standard deviations. In this study, replacing the scores of outliers was applied relying on the third option. The next section investigates bivariate outliers.

Identifying bivariate outliers

Bivariate outliers have been checked using scatter-plots and no significant outliers have been detected. The following section examines multivariate outliers and influential cases.

Identifying multivariate residuals

Residuals indicate the variation between observed and predicted values of predictor variables. This causes the violation of the assumptions of regression model as the employed technique in this research related to linearity, normality and homoscdasticity. Residuals can be investigated through looking for outliers and influential cases.

(1) Multivariate outliers

Outliers have a negative influence on the accuracy of regression model and might result in biased estimation. To examine multivariate outliers a *scatterplot of standardised residuals* and *Mahalanobis distance* are used. The following scatterplot shown in figure 6-2 shows standardised residuals plotted against supply chain visibility as the predicted dependent variable. It depicts outliers that are cases with standardised residuals of more than +3 or less than -3 (Field, 2005). Relying on the residual plot, all residuals fall between 3 and -3; therefore no outliers were detected.

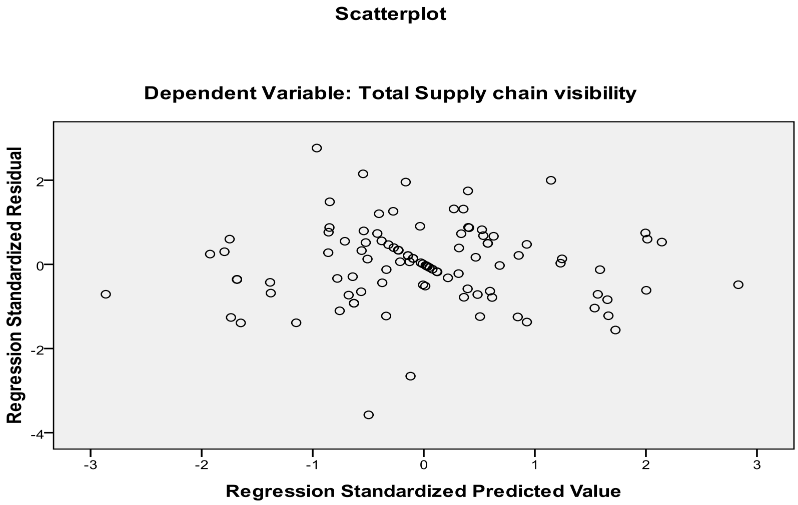


Figure 6-2: Scatterplot of standardised residual

Multivariate outliers can also be checked using *Mahalanobis Distance*. It measures how much variation between the cases' values on the independent variables and the average of all cases. It gives a common measure of multidimensional centrality and allows for significant testing through its statistical properties (Hair et al., 1998). In this research, based on this measure, if the number of independent variables is 10 (including 5 predictors and 5 control variables), the critical value of Mahalanobis distance is 29.59 (Tabachnick & Fidell, 2007). Any cases that exceed this value should be removed. The results of residual statistics indicated that the maximum value of Mahalanobis Distance is 23.717 confirming that no cases exceeded the critical value. Hence, no cases with substantial influence were detected which confirms the accurate representation of the model to actual data.

(2) Influential cases

An influential case is a case that has substantial influence over the parameters of the model. Influential cases affect the stability of the regression model across the sample. As such, the model may be biased by these influential cases (Field, 2005). *Casewise Diagnostics* measure detects the cases that have standardised residual values greater than + 3.0 or less than – 3.0. Given a normally distributed sample, it is expected that only 1% of cases are distributed outside this range. In this study's sample, there is one case (case 33) with standardised residual values of -3.576. This case recorded supply chain visibility of 33.000, but the model predicted a value of 62.0977, see table 1. Hence, the model failed to predict the value of visibility for this case as it actually has much less visibility than the predicted value. Further investigation is required to decide about the influence of this case on the parameters of the regression model. Hence, Cook's distance and Leverage/Hat value are used.

Table 6-1: Casewise Diagnostics[a]

Case Number	Std. Residual	Supply chain visibility	Predicted Value	Residual
33	-3.576	33.000	62.0977	-29.09774

a. Dependent Variable: Supply chain visibility

Cook's distance is a measure of the overall impact of a specific case on the whole model. It is suggested that values more than 1 indicate major problems (Tabachnick & Fidell, 2007, p.75). The results indicated that the maximum value for Cook's Distance is 0.499 proving that none of the cases have an undue influence on the model. *Leverage/hat value* measures the influence of the observed value of the dependent variable over the predicted values (Field, 2005). Leverage values can fall between 0 (i.e. the case has no influence over prediction) and 1 (i.e. the case has full effect on the model). It is recommended that Leverage values that exceed the cut-off point are influential cases (Stevens, 1992). The cut-off point is calculated as a three times the average ($3(k + 1)/n$) in which k is the number of predictors in the model and n is the number of cases. In this research, the Leverage value equals .324 (3(10+1)/102). The residual statistics results indicated that the maximum Leverage value of all cases is .235 which is less than the cut-off point confirming that no influential cases were detected. Therefore, relying on the criteria of Mahalanobis distance, Cook's distance, and average leverage value, it can be concluded that there are no significant outliers or influential cases within the data set. The following section examines the measurement of the research constructs and associated properties mainly through exploratory factor analysis.

6.3 Construct measurement

This section is concerned with quantitatively examining the constructs used in this research that have been theoretically validated based on literature (see refined research model, figure 5-15, p.235). Each construct represents either an independent or dependent variable, that is measured through a number of indicators constituting multi-items scale. The decision about the items of each scale has been made through reviewing associated literature confirming their content validity. In addition, pre-testing of the measurement instrument has been conducted with academics and professionals in operations and supply chain management resulting in purified and refined scale items. The survey instrument used in the study is attached in appendix J, p.455. Exploratory factor analysis and Cronpach coefficient Alpha are employed to statistically examine the quality of these constructs and their related scales in terms of their validity and reliability. The following section draws on factor analysis and its associated procedures.

6.3.1 Factor analysis procedures

Hair et al. (2010) summarise the process of factor analysis decisions in seven stages associated with estimation, interpretation and validation of the factor models. In each stage, there is a decision that must be made based on certain criteria. The following sections draw on each of these stages. Figure 6-3 provides a flowchart of factor analysis decisions.

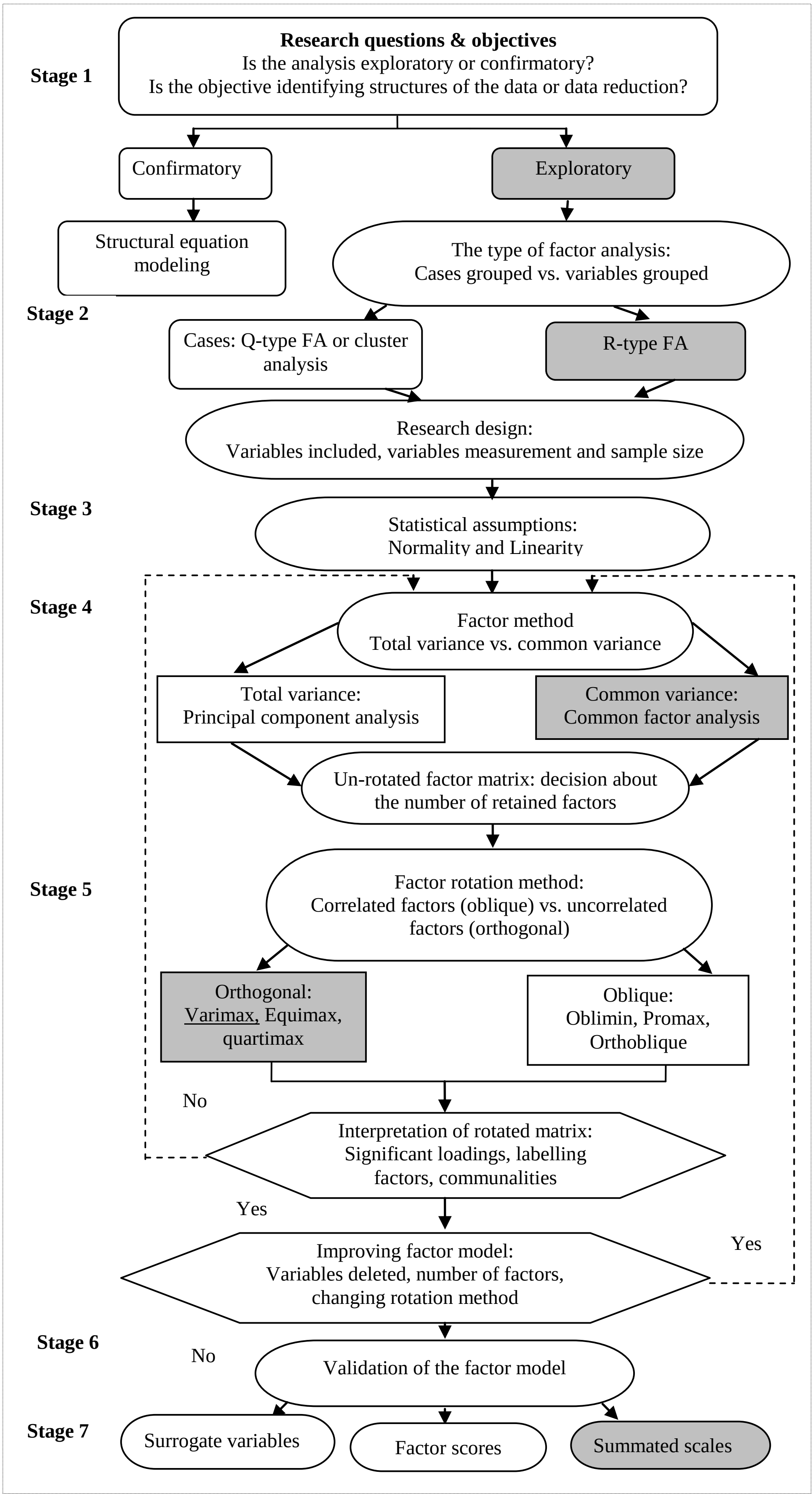


Figure 6-3: Factor analysis stages
Source: Adapted from (Hair et al., 2010, pp. 97-106)

Stage1: Exploratory versus confirmatory factor analysis

There are two main types of factor analysis; exploratory and confirmatory. The former is associated with development of theory while the latter is concerned with theory testing (Hair et al., 1998). This study is interested in investigating the key factors influencing asset visibility as a relatively new construct within supply chain context seeking theoretical support of the adopted theory. Exploratory factor analysis (EFA) is more appropriate for this study as it explores the nature of the constructs reflecting a set of responses. In addition, the key objective of conducting EFA is to summarize the data and to identify if their structure is conceptually validated.

Stage 2: factor analysis type

To calculate the input data as the first step in designing factor analysis, two forms of analysis should be considered; R-type versus Q-type factor analysis. R-type factor analysis uses the traditional correlation matrix i.e. correlations among variables as input. For the purpose of identifying similar individual respondents, Q-type factor analysis uses the correlation matrix that is calculated based on correlations among respondents. To answer the research questions and to achieve the objective of conducting factor analysis, R-type matrix is employed in this research.

Stage 3: prerequisite assumptions of EFA

This section illustrates the prerequisite statistical assumptions that ensure the suitability of EFA to be used in this research. These assumptions are related to sample size, correlations between variables, normality and linearity. Following sections examine theses assumptions.

Sample size

One of the main concerns when using FA is to have large sample size in which the estimated correlations are more reliable. The size of the required sample relies on some factors such as the magnitude of population correlation and number of factors. Small sample size is appropriate if the correlation is strong and factors are few. It is suggested that sample size of less than 50 cases should not be used with FA while one with 100 or larger is preferable (Hair et al., 1998). Based on participant to variable ratio, it is suggested that the researcher should have 10-15 participants per variable, yet the empirical basis of this rule is unclear (Field, 2005, p. 639). Some authors recommend having 5-10 participants per variable and consider 300 as the maximum regardless the rule of participant to variable ratio (Hair et al., 1998; Tabachnick & Fidell, 2007). Although some authors see a sample of 100 cases as poor, in some circumstances 100 or even 50 is sufficient (Tabachnick & Fidell, 2007, p. 613). Field (2005) argues that reliability of factors can be confirmed regardless the sample size if a factor has four or more loadings greater than .6. Furthermore, it is contended that small sample size (less than 100) is perfectly sufficient if all communalities above .6 (MacCallum, Widaman, Zhang, & Hong, 1999). Bigger samples between 100 and 200 are required with communalities in the .5 range and few factors. Sample of 500 is used with communalities less than .5 and large number of factors. In this research, the adequacy of the sample size which is 102 has been confirmed as most of factor loadings are greater than .6 (only 4 loadings out of 43 are < .6); this will be explained within stage 5. Besides, almost all communalities' values are above .6.

Sampling adequacy can be statistically measured by the Kaiser-Meyer-Olkin (KMO) test, representing the ratio of the squared correlation between variables to the squared partial correlation between variables (Field, 2005, p. 640). KMO values may vary between 0 (indicating diffusion in the pattern of correlations leading to inappropriateness of factor analysis) and 1 (values close to 1 reflect relatively compact patterns of correlations that can be classified in distinct and reliable patterns based on factor analysis). It is recommended that values of 0.5 and less than .6 are hardly accepted. Values between .6 and .7 are good, values between .7 and .8 are very good, excellent values are those between .8 and .9, and more than .9 are outstanding (Field, 2005; Hair et al., 1998). It is claimed that values of .6 or above is a prerequisite for conducting FA (Tabachnick & Fidell, 2007). In this research, the results show KMO value of 0.816 indicating the adequacy of the sample size.

Correlation among variables (R-matrix)

The strength of correlations among variables is another indicator for the appropriateness of FA. If there are relatively high numbers of coefficients greater than 0.3, so that FA is appropriate (Tabachnick & Fidell, 2007). Based on visual inspection of the correlation matrix, 54% of the correlation coefficients are greater than 0.3. This means that more than half of the variables correlate well, which is one of the prerequisites for using factor analysis (Hair et al., 1998). Although some degree of multi-collinearity is allowed for FA, extreme multi-collinearity (variables that are very highly correlated) may be a problem (Field, 2005). Hence, extreme multi-collinearity or singularity (variables that are perfectly correlated) were checked based on visual inspection of the correlation matrix. Two items were detected having correlation coefficients greater than 0.9. These two items were removed from the analysis.

Assessing univariate normality

Although normality is not a must before launching FA, findings are considered relatively strengthened in terms of generalisability if normality assumptions are attained for all variables (Field, 2005; Tabachnick & Fidell, 2007, p. 641, p. 79). Normality can be examined by either *graphical* or *statistical* methods. In considering statistical methods, Skewness (reflecting the symmetry of the distribution) and kurtosis (reflecting the peakedness of the distribution) are the two indicators of normality. Non-normal kurtosis underestimates the variance of a variable. Brown (1997) contended that kurtosis falling in the range of ±1.7 and skewness falling within the range of ±0.8944 are regarded as accepted deviations as they do not cause a severe normality problem. Visual inspection of the values of both Kurtosis and Skewness (after the remedies of outliers) reveals no deviations from these suggested ranges, on the contrary most of the variables values are considerably less than these limits and close to zero. Hence, normality can be inferred.

The visual inspection of the distributions of most variables shows that distributions of most variables represent a bell-shaped curve whilst the rest of variables are relatively close to it. In addition, the expected normal probability plots were checked and almost all the cases fall along the diagonal from lower left to upper right. Unlike expected normal probability plots, detrended expected normal probability plots plotted the deviations from the diagonal on a horizontal line rather than the values along the diagonal. Skewness and Kurtosis can be deduced if there is a cluster of points above or below the line. The visual inspection of all variables indicates no clusters or no significant deviations from normality. Hence, normality assumption for single variables has been met.

Linearity

Linearity indicates that the relationships among pairs of variables are linear. As factor analysis is based on correlation, absence of linearity negatively affects the analysis (Tabachnick & Fidell, 2007). Linearity can be checked through visual inspection of scatter plots of all variables with all other variables. However, it is not practical to do this. Tabachnick and Fidell, (2007) suggest a spot check of scatter plots of some combination of variables. Transformation of variables is required if non-linearity detected. In this research, visual inspection of scatter-plots of some correlations among pairs of variables showed that the linearity assumption is confirmed.

Bartlett's test of sphericity

Bartlett's test of sphericity is another statistical method for deciding about the adequacy of FA that examines the entire correlation matrix. It indicates the level of significance among at least some of the variables within the correlation matrix (Hair et al., 1998, p.99). The results (Chi-square $\chi^2 = 2473$, $p<.000$) revealed a significant correlations between all variables that rejects the null hypothesis that inter-correlation within the data set is not significant. As such, the adequacy of FA has been proved.

KMO statistic for individual variables

This can be checked through scanning the values of the diagonal of the anti-image matrix, these values should be more than 0.5. The initial inspection of the anti-image matrix of covariance and correlation has indicated 7 variables less than 0.5 that were defined as problematic variables and therefore subjected to deletion.

Stage4: EFA methods

There are two main operational objectives of conducting EFA; (1) to get a group of common factors represented through a number of measures, (2) to assess the strength of the relationship between each of these factors and each observed measure (DeCoster, 1998). To this end, EFA works through describing and summarising data based on categorising variables that are correlated without any theoretical logic in choosing the grouped variables (Hair et al., 1998). There are two key approaches to conduct EFA, specifically factor extraction: Principal component analysis (PCA) and common factor analysis. PCA is described as a data reduction technique that doesn't consider the underlying structure produced by latent variables as components or factors are calculated based on all the variance of the employed variables i.e. specific variances as well as shared variance in the solution i.e. common variance (Costello & Osborne, 2005). The key concern about PCA is that it does not differentiate between common and unique variance that may result in measurement error due to the inflated variance in the case of uncorrelated factors and moderate communalities (Gorsuch, 1997; Hair et al., 1998). Therefore, although, it is the most widely used as a default method of many statistical software packages including SPSS, PCA is not the best option for conducting EFA (DeCoster, 1998; Floyd & Widaman, 1995). On the other hand, common factor analysis aims at extracting any latent variable or factor causing variables to covary. To determine the underlying factor structure, common factor analysis is only concerned with common variance of each variable rather than unique variance, so that measurement error is eliminated through avoiding the inflated values of variance (Costello & Osborne, 2005). In this study, the researcher does not aim at data reduction as she has an initial idea about how the employed variables covary based on extensive literature review and the pre-conducted exploratory study (Floyd & Widaman, 1995). The researcher seeks a solution that considers only common variance when revealing the underlying structure of factors that causes the employed variables covary. In this research, common factor analysis is an adequate approach for conducting EFA.

Factor extraction technique

Factor extraction relies on linear components i.e. factors within the data set. There are a number of techniques used to extract factors, including principal component analysis, maximum likelihood, principal axis factoring, unweighted least squares, generalised least square, alpha factoring, and image factoring. There is a scarcity of information about the differentiation criteria between most of these techniques that justifies the popularity of PCA as a default method of most statistical software packages regardless of any downsides (Costello & Osborne, 2005). One of the available criteria to decide about the adequate method is related to multivariate normality. It is contended that if multivariate normality assumption is relatively confirmed, the maximum likelihood technique is the best option (DeCoster, 1998). However, if the normality assumption is crucially violated, principal axis factors is one of the recommended methods for extraction (Fabrigar, Wegener, MacCallum, & Strahan, 1999). In this study, normality assumption has been confirmed which justifies the use of maximum likelihood for factor extraction. As such, a number of extracted factors were revealed. The following step is to decide about how many factors to retain.

Factor retention

Two key techniques used to decide about the number of factors retained are eigenvalues as a statistical technique and a scree plot as a graphical technique. *Eigenvalues* (also called latent root) reflect the criteria of the importance of certain factor as they indicate the amount of variance explained by a factor (Hair et al., 1998). Therefore, factors with relatively large eigenvalues are retained and those with relatively small eigenvalues are ignored. However, the decision about how large should be eigenvalues to retain the factor is arguable. SPSS uses Kaiser's criterion to extract factors based on eigenvalues greater than 1 (Field, 2005). Based on the Kaiser criterion, the analysis provided 8 factors with initial eigenvalues greater than one that explain a total of 73.361% of the variance by their linear components. Although eigenvalues criterion is widely used, it is claimed that it is not an accurate method (Velicer & Jackson, 1990). Scree plot as the only available graphical method in most statistical software packages may be more reliable (Costello & Osborne, 2005). A *scree Plot* is a graphical technique through which factors can be selected. It is recommended retaining all factors above the elbow point at which the shape of the curve changes direction and becomes horizontal as these factors explain most of the variance between cases (Pallant, 2007). Although scree plots are valuable, they should not be used as a single measure.

The scree plot shows that point six (elbow point) starts a horizontal line and above this point there is a remarkable change in the direction of the curve represented through five factors, (Figure 6-4). These factors are retained as they explain most of the variance (64.425 %) between cases in the data set. Whilst, above point 12 there is also a slight change in the direction of the curve, the contribution of related factors (6-11) in explaining the variance is relatively small.

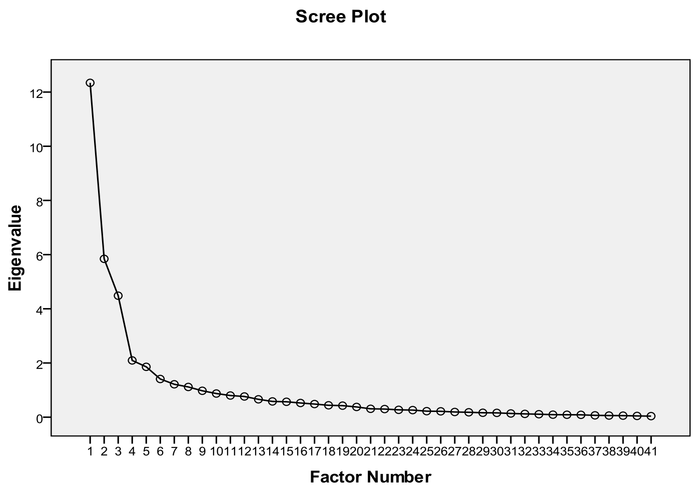


Figure 6-4: Scree plot

Because the two criteria i.e. scree plot and eigenvalues often give different solutions, communalities are considered. The closer the communalities are to 1, the better the factors explaining the original data. The more factors extracted the larger the communalities will be. The results indicate that almost all communalities are greater than .7. It is contended that the interpretation of FA as an exploratory technique is up to the researcher's judgment that should be objective and based on a robust theoretical foundation, rather than simply hard statistical rules, (Pallant, 2007, p.190). Hence, five factors were retained where the total variance explained is 64.425% which is accepted in social science research (Hair et al., 1998).

Stage5: Factor rotation

After extracting the five factors, the loading of the variables on each factor is calculated. Although unrotated factor solution (matrix) achieve the goal of data reduction, it may not provide a meaningful pattern of variable loadings as most variables have high loadings on the most important factors and low loading on all other factors (Field, 2005; Hair et al., 1998). Hence, the interpretation of factors is hard. Factor rotation is an important technique in interpreting factors as it discriminates between factors and simplifies their structure (Tabachnick & Fidell, 2007).

There are two types of factor rotation: *orthogonal* and *oblique*. The former assumes that any underlying factors are independent or uncorrelated while the latter assumes that underlying factors are correlated to each other (Field, 2005, p.625). It is claimed that orthogonal rotation is more widely used compared to oblique rotation as the former has a robust analytical procedures whereas the latter is not as well developed and subject to considerable controversy (Hair et al., 1998, p.109). If regression is used after factor analysis, orthogonal technique is recommended to avoid multicollinearity problems (Hair et al., 1998, p. 110). Tabachnick and Fidell (2007) claim that in practice both approaches often lead to very similar solutions especially when the pattern of correlation is clear. Since the key goal of rotation is to attain simple structure in which each variable loadings strongly on only one factor, it is accepted to conduct both techniques (orthogonal and oblique rotations) and choose the easiest and clearest one to interpret (Pallant, 2007, p. 183). Besides, it is claimed that the decision on an orthogonal or an oblique rotation should consider the research problem and objectives. In this research the main focus is to examine the factors that are associated with asset visibility and might influence supply chain visibility that will be tested using multiple regressions model. The researcher has conducted both techniques through which orthogonal rotation has revealed clearer interpretation. As such orthogonal rotation has been employed.

There are three key approaches for orthogonal rotation: quartimax, varimax, and equamax. *Equamax* is a hybrid of both quartimax and varimax. The difference between these methods is related to how they rotate the factors that affects the output. *Quartimax* and *varimax* are seen as opposite techniques. The former works through maximising the spread of a variable's factor loadings across all factors, the latter focuses on maximising the dispersion of loadings within factors (Field, 2005). Although quartimax can easily interpret variables, it causes many variables to load highly on one factor. Varimax leads to more interpretable factors as it allows smaller number of variables to load highly on each factor. As such, varimax is used as it provides better interpretation of factors.

Criteria for the significance of factor loadings

Once the rotated matrix provides the factor structure of asset visibility capabilities represented through a number of factors, the decision on which variables should be assigned to which factor is made. The larger the factor loading, the more important is the loading in interpreting the factor matrix. It is argued that if a factor has four or more loadings above .6 then it is reliable regardless the sample size (Field, 2005, p. 640). In the final factor solution, three factors have more than four loadings >.6, (Table 6-3, p.263). In considering sample size of 100 or more, Hair et al. (1998, p. 111) recommended that factor loadings of more than .3, explain 10% of the variance and are barely important; loadings of .4 or greater are more significant explaining 16% of the variance in a variable; and those are .5 or more explain 25% of the variance and are practically significant. Statistically, same authors recommend that in a sample of more than 100 cases, factor loadings of .50 or more are statistically significant based on a power level of 80%, and a significance level (α) of .05. Although factor loadings with an absolute value of .3 are used as significant, it is recommended that only factor loadings with an absolute value greater than .4 should be considered (Stevens, 1992). It is argued that the larger the number of variables being analysed allows smaller loading to be considered significant (Hair et al., 2010).

In this research, considering a sample of 102 cases and 59 initial variables, all loadings greater than .45 are considered significant. The final factor solution shown in table 6-3 illustrates that all loadings are significant as they are greater than .50 except only four loadings >.45 that are still statistically significant.

Refining the preliminary factor solution

For the purpose of attaining a conceptually and operationally acceptable structure of factors constituting the capabilities of asset visibility, the preliminary factor solution needs refining. Hence, a number of iterative procedures have been followed for deleting problematic variables. This entails re-run the analysis after every deletion until reaching the final solution where no more refining can improve the interpretability of the factor structure (Hair et al., 1998). Here are the criteria used for deleting problematic variables:

1. Based on the visual inspection of the correlation matrix, any variable shows extreme multicollinearity or singularity (i.e. $R > .9$) has been deleted as well as any variable does not correlate with any other variables (i.e. $R =0$);
2. Across Anti-image matrix correlations, any absolute value on the diagonal that is less than .5, the associated variable is deleted;
3. Any variable which has communalities less than .6 is deleted;
4. In considering factor loadings, a variable is deleted if:
   a- It has no loadings;

b- It has significant/non-significant cross loadings (i.e. more than one non-significant loadings and/or more than one significant loadings);

c- It has single loading constituting a one item-factor.

5. Reliability value of Cronbach's alpha of each scale forming the factor should be greater than .7. In considering Alpha value if an item is deleted, when any of these values is higher than the Chronbach coefficient alpha value, the associated variable should be deleted from the scale (Pallant, 2007, p.98).

Upon employing these criteria, 16 iterations have been performed to refine the solution that is resulted in deleting 15 variables. Table 6-2 provides a summary of deleted variables based on these criteria.

Table 6-2: Variables' deleted to refine factors' structure

Criteria	***Deleted variables***	***No***
Multicollinearity/singularity	• Locating specific asset • Common definition of SC data • Account receivable automatically triggered upon shipping	3
Anti-image matrix (diagonal values < .5)	• Openness and teamwork are encouraged® (.494) • Informal face-to-face meetings® (.486) • Inventory holding is minimized (.499) • Finding someone to blame rather than finding a solution® (.358)	4
Communalities < .6	- N/A	0
No loading	• Downstream partner shares actual sales data	1
Non-significant cross loadings	• Distribution network minimises SC inventory	1
Significant cross-loadings	• Reducing delivery errors	1
Single loading	• Single central information system • Relationship based on trust • Delivery time reduction • Information sharing arrangements	4
Chronbach's alpha if item deleted	• SC inventory is jointly managed with suppliers	1
Total deleted items		15

Drawing on the previous table showing deleted variables, two variables associated with *focal firm-3PL relational orie*ntation capability were deleted (relationship based on trust

® Reverse worded variable.

and information sharing arrangements). Three variables including locating specific asset; reducing delivery errors; and delivery time reduction are conceptually affiliated with *asset management capability* were deleted. Only one variable was removed (common definition of supply chain data) related to *IT infrastructure for supply chain integration*. Five variables were deleted concerned with *supply chain process integration capability* as follows: account receivable automatically triggered upon shipping; inventory holding is minimised; downstream partner shares actual sales data; supply chain inventory is jointly managed with suppliers; and distribution network minimises supply chain inventory. Finally, with respect to the conceptual construct of *internal integration*, four variables were removed: openness and teamwork are encouraged; informal face-to-face meetings; finding someone to blame rather than finding a solution; and single central information system.

The researcher justifies the deletion of the previous variables that in most cases, their concepts are interrelated with other variables' concepts forming one factor. For example, across your supply chain inventory holding is minimized and inventory data are visible at all stages are two variables; the former was removed due to the intervening between the two variables.

Labelling final factors

As shown in table 6-3, the final factor structure came almost in line with the conceptual base preceding the analysis. Five distinct groups of variables i.e. factors can be used for further analysis. These factors are named respectively as follows: (1) focal firm-3PL relational orientation; (2) asset management capability; (3) IT infrastructure for supply chain integration; (4) supply chain process integration; and (5) internal integration capability.

Stage 6: validation of factor solution

The purpose of validating factor analysis results is to assess the degree of generalisability of these results to population and to detect any influential cases that might have an impact on the overall results (Hair et al., 2010). Generalisability can be checked based on confirmatory techniques using another sample or through splitting the original sample to assess the replicability of the results. Common factor analysis using structural equation modelling can be employed, yet it is complicated. For practical reasons, this technique was excluded. In this research to ensure generalisability and stability of factors structure, the researcher has split the sample based on early and late respondents so that a comparison between factor analysis results of each sample was held. The results of both groups revealed a very similar factor structure that confirms the stability of the structure of the factors as well as generalisability. In considering detecting influential cases, checking univariate and bivariate outliers has indicated non-significant impact of detected outliers. Multivariate outliers were checked that indicated only one case with a standardised residual value less than –3.0. Further investigation confirmed that this case has no influence on the results.

Stage 7: creating composite measure for reflective variables

For the purpose of subsequent statistical analysis, creating a composite measure of a group of single variables (reflective variables) representing a factor (latent variable) is needed. Three key options are available: selecting surrogate variables, factor scores and creating summated scales (Hair et al., 2010). A *surrogate variable* is a single variable with the highest factor loading that is used as a representative for a specific factor dimension. Although it is simple and maintains the original variable, a single surrogate variable does not consider the problem of measurement error of other variables forming the same factor and risks potentially misleading results (Hair et al., 2010).

A *factor score* is a composite score for each participant on a certain factor (Field, 2005, p.628). It can be produced automatically within the output of EFA using SPSS. Factor scores are not a practical technique for further hypothetical testing or for examining the reliability of factor scores considering the limitation of its replication in other studies.

The most widely used method is creating a *summated scale* for each factor based by calculating the arithmetic mean of variables forming each scale/factor (Pallant, 2007). This method facilitates further statistical investigation of created measures and can be easily replicated. Using summated scale reduces the measurement error (i.e. the extent to which the variable consistently and accurately measures the investigated concept) associated with measured variables (i.e. the deviation between observed values and actual values) by using multiple variables or indicators (Hair et al., 2010). Summated scale also allows the representation of multiple aspects of a construct in a single measure.

6.3.2 Summary of final factor solution

Table 6-3 depicts the final factor solution for the capabilities associated with asset visibility. The table shows five factors and their associated variable-to-factor loadings. The research draws on each factor.

Focal firm-3PL relational orientation capability is the first factor that explains 29.98 % of the variance between cases. This factor is formed from 13 variables (after deleting two variables) measuring the focal firm-3PL relationship capability. Three key dimensions are used to classify these variables: relational asset specificity, relational interaction routines and long term orientation. Three variables are related to *relational asset specificity* including dedicating significant investment to the relationship with focal firm; customising tools and machinery to the focal firm's needs; and 3PL's knowledge about focal firm is difficult to replace. *Relation interaction routine* as the second dimension includes seven variables: the role of 3PL in developing logistics process; in quality and improvement initiatives of the focal firm; in anticipating and resolving operative problems; in helping focal firm to learn about new technologies; in developing ways to improve cost efficiencies as well as having best practices; and dedicated team for efficient consumer response practices. *Long term orientation* dimension include three variables related to jointly established goals; long term relationship; and not taking any intentional action that hurts the relationship.

Asset management capability as the second factor that explains 13.81 % of the variance in the data set. This factor is measured through 13 indicators (3 items were deleted). This factor combines both technological and non-technological capabilities of asset management. The items representing *technological capability* are related to system ability to track assets on individual base; identify physical status; and maintain historical information. On the other hand, the items measuring *non-technological capability* based on process-related capability approach are concerned with four aspects including processing time reduction; error reduction; resource consumption reduction; and process information. Processing time reduction is measured through the ability to maintain continuous flow of products; and reducing return time of RTAs. Error reduction is measured based on two variables: reducing return errors of RTAs; and maintaining quality of products. Resource consumption reduction is assessed using three variables which include reducing inefficient consumption of resources; reducing waste associated with time and money; and improving security aspects. Process information, as the last dimension, is related to providing updated and accurate information, and minimising data capture errors.

IT infrastructure for supply chain integration capability is the third factor explaining 10.91 % of variance and includes six variables. Two key dimensions are used to classify the measures of this factor: data consistency and cross functional applications. *Data consistency* is represented through two variables that include the use of automatic data capture systems, and the consistency offered in storing the same data across a supply chain. C*ross functional applications* are represented through four variables which include the ability of transaction applications to be communicated in real time; the ability of planning applications to be communicated in real time; the ability of supply chain applications to be communicated with internal firm's applications; and the ability of customer relationship applications to be communicated with internal firm's applications

Supply chain process integration capability as the fourth factor explains 5.18 % of the variance between cases and is represented through seven variables after deleting five variables. Three key dimensions are used to classify the measures of this factor in terms of physical, financial, and information flow integration. *Physical flow integration* is indicted through one variable (three variables were deleted) which is delivering products and material just in time across a supply chain. *Financial flow integration* is measured by one variable after deleting another one. This variable is about automatically triggering accounts payable upon receiving supplies from suppliers. *Information flow integration* consists of five variables including sharing production; delivery schedules and performance metrics; collaboration in arriving at demand forecasts; visibility of demand levels; and visibility of inventory data.

Internal integration capability is the fifth factor explaining 4.54 % of the variance in the data set that is measured using four indicators after removing four variables. The measures used to assess this factor are related to internal management communications; routine scheduled meetings among various departments; proper communication channels between departments; and using cross functional teams to solve problems.

Table 6-3: Asset visibility capabilities factor solution

Variable	Focal firm-3PL relationship	Asset management	IT infrastructure	SC process integration	Internal integration
Your key logistics service provider..					
..is involved in developing your logistics processes	.900				
..is involved in quality and improvement initiatives	.893				
..has dedicated significant investment to your relationship	.845				
..and you have planned to anticipate and resolve operative problems	.790				
..help you to learn about new technologies and markets	.774				
..and you have jointly established goals	.762				
..has knowledge about you that is difficult to replace	.732				
..and you have developed ways to improve cost efficiencies	.709				
..and you share best practices	.703				
..has customized tools and machinery to your needs	.676				
..and you have a dedicated team for your CRP and ECR practices	.609				
..and you have a long term relationship	.517				
..and you do not take any intentional actions that can hurt the relationship	.499				
Your tracking system for your core product helps you to..					
..provide updated information e.g. expected delays		.841			
..track RTAs on individual base across your supply chain		.828			
..identify the current physical status of your RTAs		.800			
..maintain historical information of RTAs used in your supply chain		.770			
..reduce inefficient consumption of your resources		.767			
..minimize errors in data capture		.758			
..improve security aspects e.g. loss, counterfeiting, and theft		.755			
..maintain continuous flow of products across your supply chain		.726			
..reduce return time of empty RTAs		.713			
..provide accurate information e.g. check out/in		.698			

activities					
..reduce return errors of RTAs		.687			
..maintain quality of your products across supply chain operations		.655			
..reduce waste associated with time and money		.597			
Your IT infrastructure..					
..allows transaction applications to be communicated in real time			.833		
..allows planning applications to be communicated in real time			.763		
..supports the use of automatic data capture systems across your SC			.721		
..offers consistency in storing the same data in different databases			.623		
..allows SC applications to be communicated within your firm			.618		
.. allows customer relationship applications to be communicated with internal applications			.601		
Across your supply chain..					
..production and delivery schedules are shared				.822	
..SC members collaborate in arriving at demand forecasts				.757	
..performance metrics are shared				.699	
..demand levels are visible				.562	
..Accounts payable are automatically triggered upon receiving supplies				.478	
..inventory data are visible at all stages				.471	
..products and material delivered just in time				.456	
Within your firm..					
..internal management communicates frequently about goals					.706
..formal meetings are routinely scheduled among various variables					.699
..there are proper communication channels from one department too another					.588
..cross functional teams are used to solve problems					.542
Variance explained	*29.98*	*13.81*	*10.93*	*5.18*	*4.54*
Eigenvalues	*12.89*	*5.937*	*4.70*	*2.23*	*1.95*

Extraction method: Maximum Likelihood
Rotation method: Varimax with Kaiser Normalisation
Rotation converged in 6 iterations
All loadings <.45 deleted
15 variables were deleted

Creating summated scales for formative indicators

Following the same logic of creating summated scales for reflective indicators of factors or latent variables, three summated scales were created for formative indicators representing three concepts within the research conceptual model. These were supply chain visibility; firm's performance; and sustainable competitive advantage.

6.3.3 Data quality of summated scales

Four issues need to be confirmed to ensure data quality of summated scales including conceptual congruence, unidimensionality, reliability, and validity.

Conceptual definition is influenced by a deep theoretical understanding based on intensive literature review of constructs beyond summated scales. This entails defining each concept within a specific construct that should match the research context. Thus, content validity can be attained.

In this research, developing reflective summated scales were informed by conceptual definition that justified the inclusion of each indicator in the related scale. To assess the correspondence between each indicator and its associated concept, pre-testing of measurement instrument by academics and professionals in the operations management field were conducted. In addition, in most cases the researcher intended to use measures that are already validated in previous research. The final factor model shows that each indicator has been loaded on the construct that it conceptually represents, confirming conceptual congruence. As such *content validity* as well as *face validity* of the measurement instrument is confirmed (Ahire & Devaraj, 2001; Neuman, 2006).

Unidimensionality is essential to create summated scales as each indictor should be represented only through one factor. EFA as well as confirmatory FA are techniques used to check unidimensionality of variables based on extracting a number of factors on which variables load (Ahire & Devaraj, 2001). This means that each summated scale consists of a number of variables that are significantly loading on a single factor (Hair et al., 2010). In this research, unidimensionality has been established within the procedures of EFA as a prerequisite for reliability and construct validation (Flynn, Schroeder, & Sakakibara, 1994; Saraph, Benson, & Schroeder, 1989). Unidimensionality has been confirmed relying on EFA results i.e. each variable significantly loaded on a single factor.

Reliability indicating consistency between multiple measurements of a variable is known as stability reliability (Sekaran, 2003). This type of reliability can be assessed using test-retest that requires replicating the measurement process based on collecting new responses at another point of time. For practical reasons, stability reliability using a test-retest method is not applicable in this research. The most widely used measure assessing reliability is internal consistency or internal reliability among indictors constituting a summated scale that confirm that all indicators measuring the same construct (Hair et al., 2010). Here are three techniques are employed to assess internal reliability:

- *Item-to-total correlation (ITTC)* measures the correlation between each item or indicator and the summated scale score. This measure should be greater than .50 to indicate internal reliability. The results indicated that all the values of item-to-total correlation are significantly, greater than .50 except one item's value related to the fourth summated scale which is supply chain process integration (.455). As such, internal reliability through high correlations between each item and summated scales is confirmed.
- *Inter-item-correlation (ITC)* indicates the correlation among items. It is recommended that its value should exceed .30. visual inspection of inter-item-correlation matrixes related to all scales illustrate that almost all correlations coefficient greater than .30 except three values (.283, .289, .296) out of 88 associated with first summated scale which is 3PL relational orientation capability. In addition, two of the 28 related to the fourth summated scale (supply chain process integration capability) are < .3. Even, these deviated values are close to .3 and they constitute very small percentage of the whole values, so that correlations among items can be inferred.
- *Reliability coefficient* using Cronbach's alpha assesses the consistency of the entire measurement scale. Internal consistency of measurement scale has been confirmed using Cronbach coefficient alpha that its value should exceeds .70 (Hair et al., 2010; Tabachnick & Fidell, 2007). The values of Cronbach alpha for the five reflective summated scales constituting asset visibility capabilities range from .813 to .945 demonstrating internal consistency of the employed scale. The highest value of Cronbach's coefficient alpha was for asset management capability while the lowest

value was for internal integration capability. Table 6-6 reports the values of Chronbach alpha for all reflective independent scales (see table 6-6, p.277).

Validity

Validity refers to the ability of an indicator, set of indicators using scale, or measuring instrument to accurately represent the concept that they are devised to measure (Zikmund, 2000). Validity can be subjectively confirmed in the form of content and face validity as previously mentioned. It can also be empirically tested in the form of construct validity including convergent and discriminant validity as well as criterion/nomological validity, including concurrent and predictive validity.

Construct validity of a summated scale (i.e. the measure is valid and its indicators operate in a consistent manner) is attained through confirming convergent and discriminant validity. Convergent validity indicates the extent to which same results are attained from different methods of a construct (Ahire & Devaraj, 2001). Although multitrait-multimethod approach is preferable to test common method variance, it is time consuming. Another accepted method is to treat each single item on a measurement scale as a different method for gauging the same construct (Ahire & Devaraj, 2001). This can be assessed through determining the degree of convergence of a group of items on the construct (Ahire, Golhar, & Waller, 1996). As such, convergent validity has been established through EFA indicating items load on an individual factor that are highly correlated with other items constituting these factors using an inter-item correlation matrix (Bagozzi, Yi, & Phillips, 1991). Discriminant validity measures the degree to which the indicators of a concept vary from other indicators of another concept. Discriminant validity has been established in this research relying on three criteria (Ahire & Devaraj, 2001). First, inter-scale correlation is significantly different from 1 (Bagozzi et al., 1991). Second, average item-to-total correlation of non-scale items is less than scale items. Third, Cronbach alpha of each of the scale is greater than the average of its correlations with other scales or constructs (Ghiselli & Campbell, 1981). The results indicated that inter-scale correlation coefficients range from .090 to .766 which is significantly different from one. In addition, for all summated scales the average item-to-total correlation of non-scale items is noticeably less than scale items. Based on calculating the average correlation between each scale and other scales and then comparing them with their Cronbach's coefficient alpha, all scale Chronbach alpha values were greater than their average correlation with other scales. As such, the three criteria have been met, which establishes discriminant validity.

Criterion or nomological validity indicates the success of summated scales in estimating or predicting other concepts under the same construct. This can be established by comparing a summated scale with another measure of the same construct in which the researcher has confidence (Neuman, 2006). This form of validity can be established through concurrent and predictive validity. *Concurrent validity* indicates the extents to which summated scales correlate with other measures within the same construct that are simultaneously measured. In this research, concurrent validity has been confirmed by measuring the correlations between all summated scales and supply chain visibility as another measure within the same conceptual model. The results revealed significant correlations between the five summated scales and supply chain visibility, proving concurrent validity. *Predictive validity*, that works in a line with concurrent validity, refers to the extent that summated scales accurately predict other measures or concepts within the same construct or conceptual model (Hair et al., 2010). In this research, predictive validity has been empirically established as the five summated scales significantly predict supply chain visibility as another concept within the research conceptual model, a detailed discussion is presented in the hypotheses testing section. Therefore, criterion or nomological validity is confirmed based on establishing both concurrent and predictive validity.

For the purpose of ensuring quality of formative summated measures, the same procedures have been applied. Conceptual definitions have been theoretically established relying on reviewing related literature. Besides, content and face validity have been subjectively confirmed as the measures of formative scales were all based on pre-existing valid measures and reviewed by academics and professionals in the field of operations management within pilot testing of the measurement instrument. Internal reliability of formative scales has been empirically proved using the same techniques i.e. ITTC, ITC and Cronbach's coefficient alpha. Internal reliability indicators for supply chain visibility indicated ITTC ranging from .728 - .858, ITC >.30 and Cronbach alpha of .969. Internal reliability measures for firm's performance illustrated ITTC ranging from .634 - .788, ITC >.30 and Cronbach alpha of 905. Internal reliability measures of SCA indicated ITTC values of almost all the items >.50 except three values that approximately close to .5, ITC of most items >.30 and Cronbach alpha of .892. The values of Chronbach alpha for formative summated scales (dependent variables) are above.7.

To sum up, the analysis of the construct measurement techniques of asset visibility as the construct adopted in this research using EFA has revealed five valid and reliable reflective summated scales. In addition, three formative summated scales have been developed and their reliability has been confirmed. Both reflective and formative summated scales are used for further statistical investigation of the underlying conceptual model. The following section discusses the assumptions of multiple regression analysis that will be employed for the purpose of hypotheses testing.

6.4 Checking multiple regression assumptions

Multiple regression analysis, as a linear modelling technique aiming at examining the relationship between more than one predictor variables and one dependent (criterion) variable is seen as an adequate multivariate statistical technique to investigate the hypothesised relationships developed in chapter five. Two types of errors are constraints for achieving the objectives of multiple regression: measurement and specification errors. *Measurement error* that indicates the extent to which a variable constantly and accurately measures the concept it was devised to measure is mitigated by the use of summated scales for both independent and dependent variables (Hair et al., 2010). To avoid *specification error,* which is related to including irrelevant variables or the omission of relevant variables, the research includes only all relevant variables where reliability and validity have been proved. Between multiple regression methods, including confirmatory specification, sequential search methods and combinatorial approach, the employed regression method in this research is confirmatory specification, mainly forced entry. This method entails forcing all predictor variables to be entered simultaneously. A good theoretical justification for the inclusion of the chosen predictors with no predetermined order supported the adoption of this method (Field, 2005; Hair et al., 2010).

To assess the accuracy of the regression model there are two consecutive issues to be checked: (1) if the model fits the observed data well or if it is influenced by a small number of cases known as residuals; and (2) the extent to which the model can be generalised to other samples. The first concern has been checked earlier within multivariate residuals section that confirmed the absence of any influential cases or outliers. This ensures that the model fits well the observed data. With regard to second concern, the assumptions of multiple regression model are discussed in the following sections.

Hair et al. (2010) state four key assumptions underlying multiple regression analysis that have to be established: (1) linearity of the phenomenon measured; (2) constant variance of the error terms known as homoscdasticity; (3) independence of the error terms; (4) normal distribution of the error term. These assumptions apply both to individual variables including dependent and predictor variables (using univariate analysis) and to the variate i.e. all linear combinations of variables representing a whole relationship (based on multivariate investigation).

6.4.1 Assessing regression assumptions for individual variables:

With regard to the examination of individual variables, univariate analysis of both dependent and predictor variables was conducted to check for aforementioned assumptions. The means and standard deviation (S.D) of each variable was examined (see table 6-6, p.277). Besides, the values of skewness and Kurtosis of each variable were reported in table 6-4 indicating no deviation from normality as all values lie within the accepted deviation range from normality (kurtosis falling in the range of ±1.7 and skewness falling within the range of ±0.8944), on the contrary most of these values are close to zero. In addition, Kolmogorov-Smirnov (K-S) normality test has been conducted for all variables and revealed non-significant difference ($p > .5$) from normality. Moreover, histograms, normal probability plots and box plots were developed to gauge the linearity, normality and symmetry of each individual variable that confirm meeting these assumptions. As such, the assumptions of multiple regression analysis have been confirmed for individual variables.

With regard to the five control variables including firm size and four types of industries, the distribution of three control variables (industry type 2, 3 and 4) are significantly away from normality. To overcome this non-normality problem, transformation based on taking the logarithm (Log10) of each variable was used. By comparing the original variables and the transformed ones using normal probability plots as well as Skewness and Kurtosis measures, better normality and linearity characteristics have been achieved.

Table 6-4 Univariate analysis of individual variables

Variable	Skewness	Kurtosis	Sig.∗ of K-S	VIF
Supply chain visibility[a]	-.306	-.348	.200	_
3PL relational orientation	-.156	-.353	.200	1.363
Asset management capability	-.404	-.457	.200	1.256
IT infrastructure for SC integration	.006	-.576	.200	1.701
SC process integration	-.143	-.365	.200	1.663
Internal integration	-.186	-.827	.092	1.424

(a) Dependent variable, (∗) p <.05.

6.4.2 Assessing regression assumptions for residuals

Residuals that represent the variation between observed and predicted values of predictor variables have an impact on regression assumption. Hence, they indicate the extent to which these assumptions are met. Here *linearity* represents the degree to which predicted dependent variable values are associated with errors of prediction and *homoscedasticity* indicates the equality of variance of the residuals (error term) about the predicted dependent variable for all predicted values (Tabachnick & Fidell, 2007). To examine linearity and homoscedasticity, scatterplots of standardised residual plotting residuals against dependent variable as well as partial plots plotting residuals against predictor variables were employed (Tabachnick & Fidell, 2007). In this research, standardised residual plots illustrated in figure 6-2 (p.246) as well as partial plots are quite similar to a desired null plot that shows a non-symmetric pattern and most of the residuals concentrated in the middle and distributed evenly around zero. This indicates no violation of linearity and homoscedasticity assumptions (Hair et al., 2010).

The third assumption, related to *the independence of error term,* postulates the independency of each predicted value that is not associated with any other prediction (Hair et al., 2010). Examining this assumption requires plotting residuals against any possible sequencing variable. Residual term should be uncorrelated for any two observations. The associated *Durbin-Watson* statistics is an indicator for autocorrelation of errors over the sequence of cases that its significance refers to non-independence of errors (Tabachnick & Fidell, 2007). It is claimed that Durbin-Watson values less than one and greater than three are problematic and cause for concern (Field, 2005). In this research, Durbin-Watson value is 2.134 confirming the independency of the error terms.

With regard to normality assumption of the distribution of error terms i.e. residuals, normality here is about examining if residuals are normally distributed which is seen as the most commonly violated assumption (Hair et al., 2010). Here normality of residuals is not assessed through normality tests as they are overly sensitive (Tabachnick & Fidell, 2007, p.613). In this research, normality of residuals has been checked through the histogram and normal probability plot (Hair et al., 1998). As illustrated in figure 6-5, the normal probability plot (P-P) shows no major deviations from normality as the points of the model are distributed in a reasonably straight diagonal line from the bottom left to top right. Besides, the visual inspection of the histogram introduced in figure 6-6 as a key graphical tool for measuring normality illustrates bell-shaped curve, with little frequencies towards the extremes.

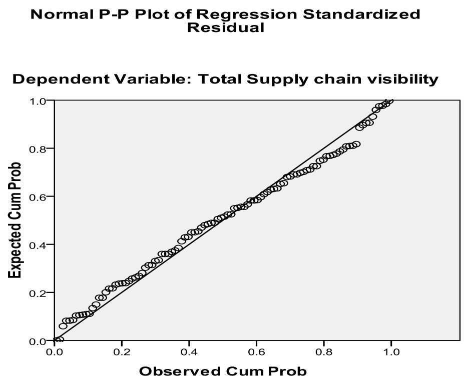


Figure 6-5: Normal P-P plot of residual

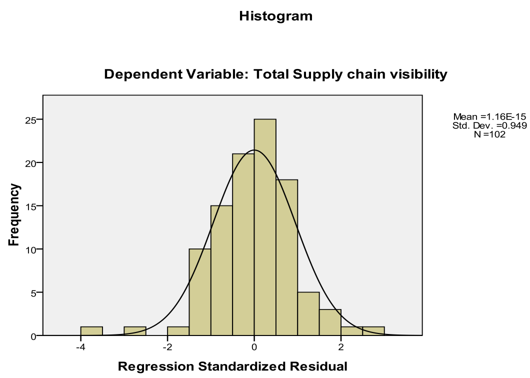


Figure 6-6: Histogram of residual

Multicollinearity

A strong correlation between two or more predictor variables in a multiple regression model indicates multicollinearity problem that the research tried to eliminate this problem through making the decision about the adoption of factor scores that are orthogonal i.e. uncorrelated as part of EFA procedures. Multicollinearity has three key negative effects on the regression model (Field, 2005): (1) it reduces the size of R and in turn R^2; the former is a measure of multiple correlation between predictor variables and dependent variable while the latter refers to the variance in the dependent variable caused by predictor variables; (2) it causes difficulty when assessing the individual contribution of a predictor variable in explaining the variance in dependent variable; (3) it leads to unstable predictor equations due to increasing the variances of the regression coefficients (the *b*-values). Multicollinearity can be detected through visual inspection of a correlation matrix of all predictor variables in which any correlations more than .8 or .9 yield multicollinearity (Tabachnick & Fidell, 2007).

In this research, visual inspection of the *correlation matrix* of all independent variables revealed a maximum correlation coefficient of .519 between supply chain process integration and IT infrastructure for supply chain integration that is less than .8. Hence, no concern should be raised about any variable. Further investigation of the correlation matrix will be made in the following section.

Collinearity diagnostics mainly *tolerance* and *variance inflation factor (VIF)* statistics are employed to assess multicollinearity. Tolerance value is the amount of a variable unexplained by the other variables. Hence, a small tolerance value is an indicator for multiple correlation with other variables. It is recommended that .10 is a cut-off point of a tolerance value (Field, 2005; Hair et al., 2010). In this research tolerance values for all predictor variables range from .588 to .936 which is > .10. On the other hand, VIF is another measure for multicollinearity that assess the strength of a linear relationship between a predictor variable and other predictors (Field, 2005). VIF is calculated as the inverse of the tolerance value. It is suggested that a VIF value of more than 10 is alarming for multicollinearity and may lead to a biased regression model (Hair et al., 2010; Myers, 1990). In this research, VIF values for all predictors range from 1.118 to 1.663. Therefore, the values of tolerance and in turn VIF confirmed the absence of multicollinearity, see table 6-4 (Univariate analysis), p.256.

Significance of bivariate correlation

The initial step before evaluating the regression model is to check the bivariate correlation of the hypothesised framework. Correlation coefficient as a standardised measure of an observed relationship between two variables indicates the strength of this relationship. It is suggested that values of .1 indicate low correlation, .3 represent moderate correlation, .5 are highly correlated (Cohen, 1988). As previously mentioned, the absence of multicollinearity has been confirmed between predictor independent variables. In this section the research draws on the significance of correlations, see table 6-6, p.277.

The results shown in table 6-6 indicate significant positive correlations between the five predictor variables and supply chain visibility as the criterion variable. Moderate correlations have been revealed between asset management capability and 3PL relational orientation capability from one side and supply chain visibility from the other side (r= .31, r= .43 respectively). In addition, strong correlations have been confirmed between IT infrastructure for supply chain integration, supply chain process integration, and internal integration capability from one side and supply chain visibility from the other side (r= .60, r= .71, r=59). These results prove a positive relationship between asset visibility capabilities represented through the five predictor variables and attaining supply chain visibility. This gives initial support to hypothesised framework that was theoretically justified and informed by pilot study findings.

In considering bivariate correlations between predictors, the research draws on each predictor variable. A*sset management* that represent the core capability of asset visibility showed significant positive correlations that range from moderate to low with other predictors including, respectively, 3PL relational orientation, IT infrastructure for supply chain integration and supply chain process integration capability (r=.31, r=.33, r=.20 respectively). On the contrary, internal integration capability as a predictor and all control variables have no significant correlation with asset management capability.

Focal firm-3PL relational orientation as a complementary capability for asset visibility indicated significant moderate to low correlations with all other predictors including asset management, IT infrastructure, supply chain process integration and internal integration (r= .31, r= .31, r= .37, r= .24 respectively) as well as firm size (r= .17) as a control variable. Yet no significant correlations with other controls were detected.

IT infrastructure for supply chain integration as a complementary technological capability of asset visibility has a strong correlation only with supply chain process integration (r= .52) and moderate correlations with other predictors i.e. asset management, focal firm-3PL relationship and internal integration capabilities (r= .33, r= .31, r= .45, respectively). However, it has no significant correlation with any control variables.

Supply chain process integration as a complementary capability of asset visibility revealed significant positive high to moderate correlations with other predictors including IT infrastructure, focal firm-3PL relationship and internal integration capabilities (r= .52, r= .37, r=.45 respectively) apart from asset management capability that showed significant low correlation (r= .2). No significant correlations with controls have been proved.

Lastly, *internal integration* has moderate to low correlations with other predictor variables i.e. IT infrastructure, supply chain process integration and focal firm-3PL relational orientation capabilities (r=.45, r= .45, r= .24 respectively) except asset management variable and other controls that showed non-significant correlations. The following table 6-5 summarises the correlations among variables including predictors and dependent. Levels of correlations in terms of high, moderate and low have been denoted as H, M and L respectively.

Table 6-5: Bivariate correlations among predictors and criterion variable

Variable	1.	2.	3.	4.	5.
1. SCV					
2. Asset management capability	M				
3. Focal firm-3PL relationship	M	M			
4. IT infrastructure for SC integration	H	M	M		
5. SC process integration	H	L	M	H	
6. Internal integration	H	L*	L	M	M

* Non-significant correlation (*p*> .05)

Table 6-6: correlation matrix and descriptive statistics

N0.	Variable	Mean	S.D[c]	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1.	Asset management capability	46.97	16.89	**.95**										
2.	Focal firm-3PL relationship	55.29	12.07	.31**	**.94**									
3.	IT infrastructure for SC integration	26.91	7.44	.33***	.31**	**.91**								
4.	SC process integration	33.23	7.31	.20*	.37***	.52***	**.85**							
5.	Internal integration	20.44	3.76	.08	.24**	.45***	.45***	**.81**						
6.	Supply chain visibility[a]	68.04	14.24	.31**	.43***	.60***	.71***	.59***	**.97**					
7.	Firm size (employees)	2.26	.92	.07	.17*	.01	-.02	-.05	-.17*	-				
8.	Industry type1	.17	.38	.08	-.07	-.09	.07	-.07	-.01	.20*	-			
9.	Industry type2	.18	.39	.04	.15	.07	.07	.03	.08	.02	-.14	-		
10.	Industry type3	.09	.29	.12	.05	-.05	.01	-.15	-.16	.10	-.14	-.14	-	
11.	Industry type4	.34	.48	-.002	-.08	.16	-.09	.10	.10	-.18*	-.32***	-.23*	-.23*	-

a) *Dependent variable*

b) *N=102*

c) *Standard deviation*

d) *Chronbach's alpha score are represented along the diagonal*

e) **p<.05, **p<.01, ***p<.001,* all one tailed test

6.5 Hypotheses testing

This section seeks to evaluate the statistical tests employed to corroborate the hypothesised framework that includes ten hypotheses, see figure 6-7. First, *standardised multiple regression* - also known as ordinary least squares (OLS) - is employed for the purpose of examining the research hypotheses associated with the positive relationship between supply chain visibility and asset visibility capabilities represented through five independent variables and five controls that are denoted as H.1+3, H.2, H.4a,b,c. Second, *bootstrapping multiple mediation analysis* is conducted for testing the research hypotheses concerned with the relationship between asset visibility capabilities and sustainable competitive advantage that is mediated by supply chain visibility and firm's performance that are denoted as H. 5+7, H. 6 and H. 8a,b,c.

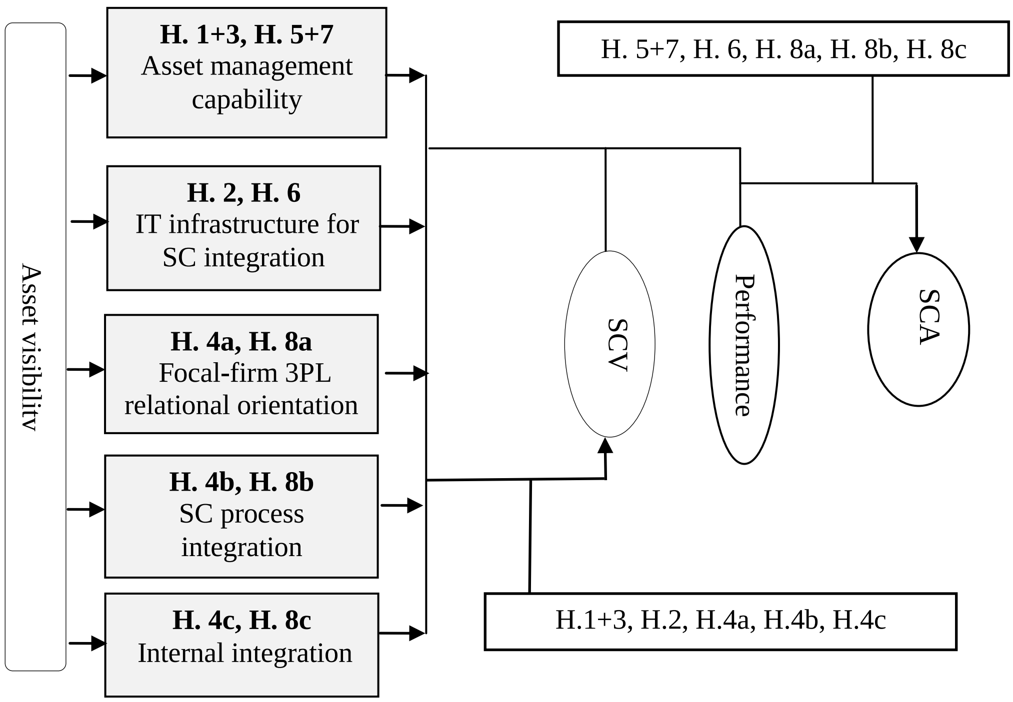


Figure 6-7: Refined research hypotheses

Regressing asset visibility capabilities to SCV

Standard multiple regression was conducted to predict supply chain visibility through asset visibility capabilities that is investigated based on testing five hypotheses H.1+3, H.2, H.4a,b,c. The results of regression model are presented in figure 6-14. First, the control variables (firm size and industry type) were regressed against the dependent variable (supply chain visibility). Second, the predictor variables that are associated with the capability of asset management, IT infrastructure for supply chain integration, supply chain process integration, focal firm-3PL relational orientation, and internal integration, were regressed against supply chain visibility as a dependent variable.

The research begins with evaluating the regression model and its significance. This will be followed by assessing each individual predictor in its association with SCV and SCA.

6.5.1 Evaluating the regression model of asset visibility capabilities on SCV

R square (R^2) indicates how much variance in the outcome variable is explained by the model. As presented in the model summary figure 6-14, R^2 value is 0.706 that can be expressed as a percentage 70.6%. This means that the model including 5 predictor variables (asset management capability, IT infrastructure for SC integration, SC process integration, focal-firm-3PL relational orientation, and internal firm integration) and five control variables (Industry type4, Firm size, industry typ2, Industry typ3, Industry typ1) is able to explain 70.6 % of the variance in supply chain visibility.

Considering the relatively small sample, it is claimed that R^2 value tends to overestimate the true value in the population (Tabachnick & Fidell, 2007). Hence, Adjusted R^2 offers better estimation of the true population values. As shown in figure 6-14, *adjusted* R^2 value is 0.674 i.e. 67.4 % that is close to R^2 value (70.6%) with a difference of 2.8%. This indicates low difference between the results drawn from the sample and the population. Hence, the cross-validity of the model is confirmed (Field, 2005). Besides, the change statistics indicates the significance of R^2 (i.e. the model significantly ($p <$ .001) causes R^2 to change from zero to .706).

Evaluating the significance of the results

ANOVA table tests whether the model is significantly better than the mean at predicting the outcome variable. In this research, the results show that the model is significantly better in predicting supply chain visibility than the use of mean ($p < 0.001$). F indicates the improvement in prediction resulting from fitting the model.

Table 6-7: Significance of the regression model results (ANOVA)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1148.593	5	229.719	1.140	.345[a]
	Residual	19340.296	96	201.461		
	Total	20488.889	101			
2	Regression	14465.051	10	1446.505	21.852	.000[b]
	Residual	6023.838	91	66.196		
	Total	20488.889	101			

a. Predictors: (Constant), IndsTyp4, Firm size, IndsTyp2, IndsTyp3, IndsTyp1
b. Predictors: (Constant), IndsTyp4, Firm size, IndsTyp2, IndsTyp3, IndsTyp1, supply chain integration, Asset management capability, internal integration, Focal-firm-3PL, IT infrastructure
c. Dependent Variable: Supply chain visibility

Evaluating each of the independent variables

For the purpose of evaluating the contribution of each predictor variable in predicting the outcome variable, the Beta value (β) as a standardised coefficient measure is used. Standardised coefficients allow the comparison between different variables based on a universal scale. In this section the research assesses, in turn the contribution of each predictor variable in predicting SCV H. 1+3, H. 2 and H. 4a,b,c.

<u>Regressing asset management capability to SCV (H. 1+3)</u>

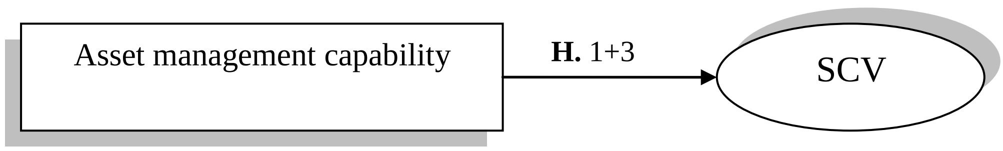


Figure 6-8: Hypothesis H. 1+3

The results of multiple regression model indicated non-significant relationship between asset management capability and supply chain visibility (β= .124, $p > .05$). This result does not confirm the pilot study findings and related theoretical support. Different research settings (e.g. persons, times, technology) may lead to different results. In addition, from a statistical perspective, the non-significant contribution made by this factor may be due to its correlations with other predictor variables in the model or because of its limited effect compared to the effects of other predictors. For further investigation, a simple regression model predicting SCV as a dependent variable through asset management capability as an independent variable has been performed. The results indicate that the model significantly ($p < .01$) explain .121 ($\beta = .121$) of the variance in SCV, see figure 6-14. In addition, simple correlation has been performed and the output indicated moderate correlation between the two variables ($r = 0.3$) that can be deduced from the following scatter diagram (Field, 2005). The scatter diagram presented in figure 6-9 confirms this result. These results illustrate that asset management capability has a significant impact on visibility that became weak upon the inclusion of other variables in the model. The other predictor variables had a magnitude effect on the model that hides the influence of asset management capability. This result confirms the associated hypothesis [H. 1+3].

This illuminates that obsolete and traditional asset management systems constituting the dominant pattern across current supply chains (see Appendix E, 394) have limited impact on SCV, in terms of information sharing and the quality of this information, compared to other asset visibility capabilities. This finding supports the extant literature, which refers to the negative impact of poor visibility due to flawed asset management systems specifically at the RTA level (cf. Johansson & Hellström, 2007; Kang & Gershwin, 2005; Martinez-Sala et al., 2009; Ngai et al., 2007a; Raman et al., 2001).

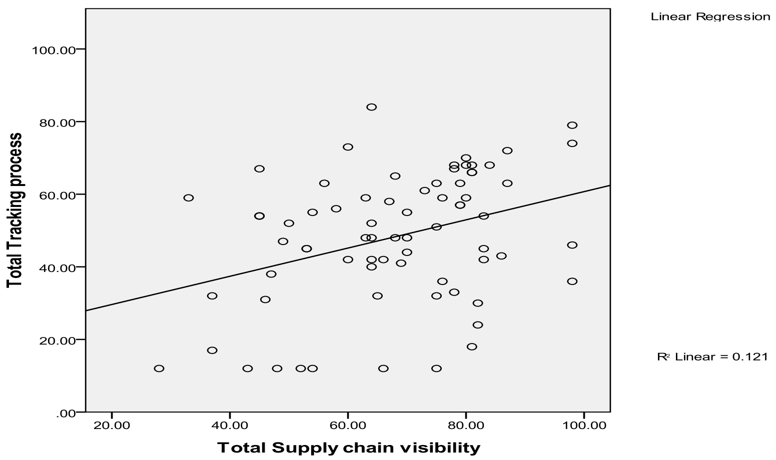


Figure 6-9: Scatter diagram of asset management capability and SCV

Regressing IT infrastructure for SC integration to SCV (H. 2)

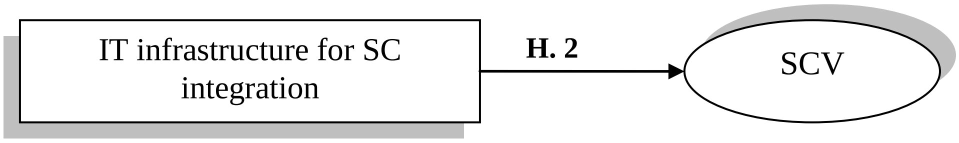


Figure 6-10: Hypothesis H.2

A significant positive relationship has been established between IT infrastructure for supply chain integration and SCV ($p< .05$). The model explains 16.9% ($\beta= .169$) of the variance in SCV through IT infrastructure for supply chain integration capability. This result proves the related hypothesis [H. 2] that suggested a positive relationship between the two variables. This finding is in line with the pilot study outcome and the associated theoretical interpretation.

Regressing supply chain process integration to SCV (H. 4a)

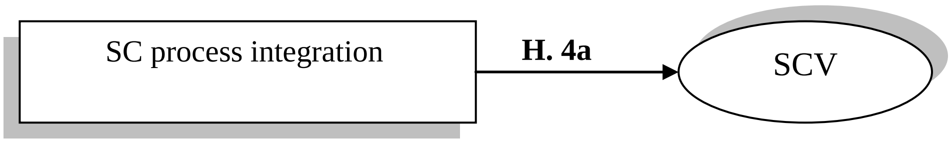


Figure 6-11: Hypothesis H.4a

Figure 6-14 shows that there is a significant relationship between supply chain process integration capability and SCV ($p< .001$). The model was able to interpret 43.4% ($\beta= .434$) of the variance in SCV though supply chain process integration constituting the largest amount of variance explained in the whole model. This result confirms the related hypothesis [H. 4a] indicating a positive association between the two variables. This finding matches the initial findings of the pilot study stage and its theoretical base.

Regressing focal firm-3PL relational orientation to SCV (H. 4b)

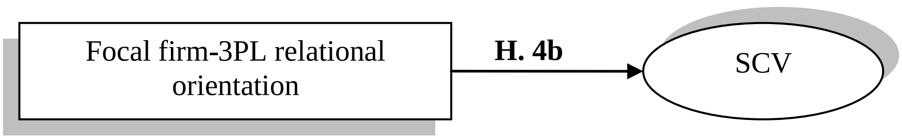


Figure 6-12: Hypothesis H.4b

Drawing on the figure 6-14, a significant relationship has been proved between focal firm-3PL relational capability and SCV ($p< .05$). 3PL relational orientation successfully explained 15% (β= .150) of the variance in SCV as the criterion variable. This confirms the positive relationship between the two variables, and thus the hypothesis is supported.

<u>Regressing internal integration capability to SCV (H. 4c)</u>

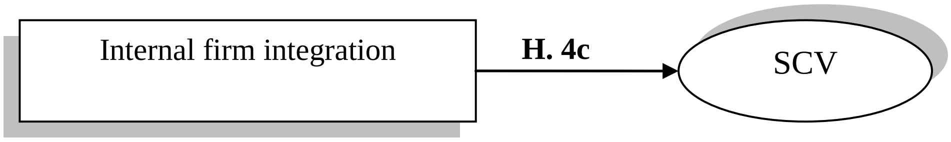
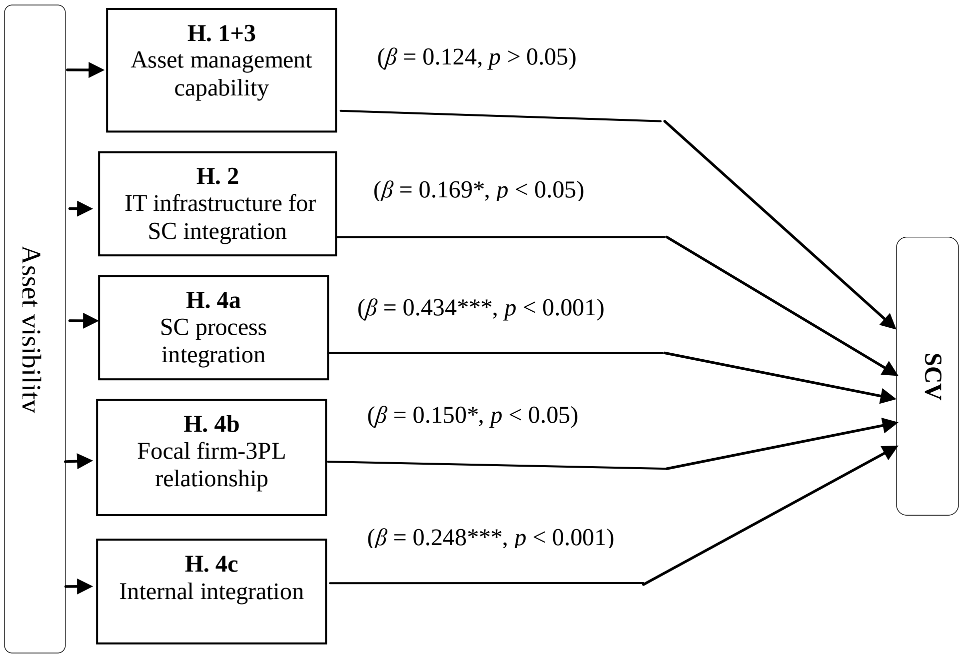


Figure 6-13: Hypothesis H.4c

The examination of the relationship between internal integration capability and SCV has revealed the significance of this relationship (p< .001), see figure 6-14. The model successfully explained 24.8% (β= .248) of the variance in SCV through internal integration capability. As such, the related research hypothesis [H. 4c] suggesting a positive relationship between the two variables has been confirmed. This result confirms the pilot study findings and its theoretical support.



	Model1	Model2
Firm size (β)	-0.151	-0.168**
Industry type1 (β)	0.041	.008
Industry type2 (β)	.088	-.007
Industry type3(β)	-.105	-.120
Industry type4 (β)	.082	.011
ΔR^2	0.056	0.650***
Overall R^2	0.056	0.706
Adjusted R^2	0.007	0.674
Overall model F	1.140	40.233***

Figure 6-14: Regression asset visibility capabilities to SCV
Note: significance at: *p, 0.05, * *p, 0.01, and * * *p, 0.001.

To conclude, the model significantly explains 70% of the variance in SCV. In addition, significant positive relationships have been proven for the four predictor variables within the multiple regression model, so that the associated hypotheses have been confirmed. Only one variable, asset management capability, was not significant within the multiple regression model. Relying on the findings of the simple regression analysis, asset management capability significantly predicts SCV. This result conservatively confirms the related hypothesis. The findings of the regression analysis came in line with the initial empirical finding based on the pilot study as well as the theoretical framework.

The following section examines the second hypotheses that investigate the relationship between asset visibility capabilities and sustainable competitive advantage, mediated by SCV and firm's performance. This section starts by providing an overview of the multiple mediation technique used for this analysis.

6.5.2 Testing the mediation effect of asset visibility capabilities on SCA

Mediation effect can be confirmed when independent variable(s) predicts dependent variable indirectly through mediator variable(s) (Preacher & Hayes, 2008). The following diagram figure 6-15 depicts the multiple mediation model with two mediators. In this model, X represents the independent variable; Y is the dependent variable. M1 and M2 indicate the mediator variables. Paths a1 and a2 show the direct effect of X on M1 and M2 respectively. Paths b1 and b2 represent the direct effect of M1 and M2 respectively on Y. Path t depicts the total effect (indirect effect) of X on Y that includes the effect of both mediators. Path d illustrates the direct effect of X on Y when (M1) and (M2) are controlled for.

In this research, supply chain visibility and firm's performance are treated as mediators (M1, M2 respectively) when testing the hypotheses measuring the indirect effect of factors constituting asset visibility capabilities as predictors Xs on sustainable competitive advantage Y as a dependent variable.

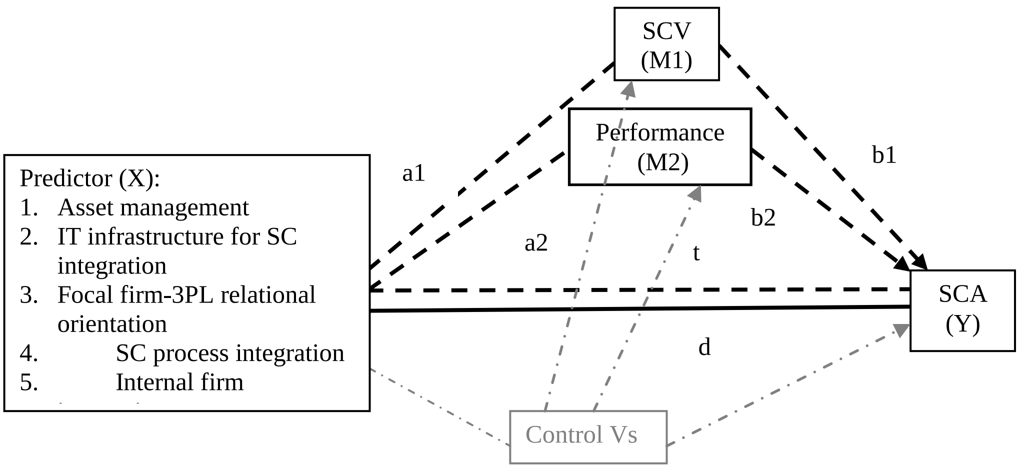


Figure 6-15: Multiple-mediation model

Investigating multiple mediation relationships includes two key steps: (1) assessing the total indirect effect (path t) of the effect of X on Y through M1 and M2; (2) testing the significance of the indirect effect of each individual mediator (t - d) within the context of multiple-mediation. Statistical significance of total indirect effect is not a prerequisite for testing a specific indirect effect (Preacher & Hayes, 2008). Recently more attention has been given to the ways of testing multiple mediation models. There are three key methods used to gauge total and specific indirect effects. These methods include a causal steps approach; the product coefficient approach (sobel test); and bootstrapping. The research draws briefly on these methods.

Causal steps approach is the most widely used technique driven by Baron and Kenny's (1986) criteria for confirming mediation. According to Baron and Kenny (1986), four conditions should be met to prove a mediation relationship: (1) total effect of independent variable X on the dependent variable Y is significant (path t); (2) independent variable X significantly predicts the mediator M (path a); (3) mediator variable M significantly predicts dependent variable Y (path b); and (4) the effect of the independent variable on the dependent variable Y is no longer significant when controlling for the effect of the mediators (path d). Causal steps approach seeks to measure the significance of specific indirect effect i.e. a1 and b1 in figure 6-15. If these two paths are not significant, so M1 is not a mediator of the effect of X on Y.

This technique was criticised as it is based on testing single paths i.e. a and b paths instead of testing the specific indirect effect (a x b). In addition, significance of the total effect of a predictor on a dependent variable (path t) is not required for confirming mediation. Mediation should only be confirmed based on the size of the indirect effect (a x b) not by the lack of the direct effect (Zhao et al., 2010). If a direct effect exists, other mediators should be considered. It can therefore, be deduced that causal steps strategy based on Baron and Kenny conditions is limited when investigating mediation models.

The Sobel test (the product of coefficient approach) is the second method. In response to the criticism of Baron and Kenny's model, sobel test is used to examine mediation models considering the product of a and b paths (a x b) as they represent the difference between the total effect of X on Y considering M and the direct effect of X on Y when M is controlled for (t – d). The Sobel test is a technique assuming that data (a x b) are normally distributed. It includes calculating the ratio of (a x b) to its estimated standard error (Preacher & Hayes, 2008). The significance of this ratio indicates the significance of mediation model based on *p* value related to standard normal distribution.

This method is criticised as usually the distribution of a x b as a product is positively skewed causing asymmetrical confidence interval that in turn diminish the power of mediation tests (Preacher & Hayes, 2004; Zhao et al., 2010). Although this limitation directly affects simple mediation models, it also extends to multiple mediation models due to multivariate normality assumption.

Bootstrapping within distribution of the product approach was developed to avoid the limitation associated with the Sobel test that the normal distribution of a x b can only be attained in large samples or when the effect is large. It is a non-parametric re-sampling technique that has no distributional assumptions. This method includes re-sampling of the data set thousands of times and each time estimating the indirect effect. As such sampling distribution of the product a x b can be approximately determined and used to build the confidence intervals (CIs) for the mediation model or the indirect effect (Preacher & Hayes, 2008). This technique is recommended in the case of small to moderate samples and to overcome the non-normality of the product a x b sampling distribution and the power problem due to asymmetries (Preacher & Hayes, 2004).

It is argued that distribution of product approach using bootstrapping is the most appropriate technique to test simple mediation models while its extension considering more than one mediator within the context of multivariate analysis fits multiple mediation models. In a multi-mediator context specifically, a two-mediator model, bias-corrected (BC) bootstrapping is a more accurate method in terms of statistical power and type I error rates when estimating the total and specific indirect effects compared to Sobel test method (Williams & MacKinnon, 2008). In addition, a pairwise contrast of indirect effects can be performed within multi-mediator models allowing a comparison between the sizes of proposed mediators' effect.

Bootstrap mediation analysis and findings

The original sample of this study is 102 cases that is re-sampled based on 5000 bootstrap resample (*k*). Hence, mediation relationship can be deduced considering both estimated total effect Σ (a*i* x b*i*) and specific indirect effects (a*i* x b*i*). The interpretation of bootstrap mediation analysis focuses mainly on the direction and the size of the indirect effects rather than the statistical significance of a and b paths (Preacher & Hayes, 2008).

As such, bootstrap confidence intervals (CIs) of the specific indirect effect through the mediators is sorted based on defining the lower and upper limits of the *k* values of a*i* x b*i* i.e. *k* (1-α) % CI (α is the accepted type I error rate). In this study, CI is 95% with α = .05. Since *k* =5000, the lower and upper limits of interval is the 125^{th} and the 4876^{th} values, respectively based on *k* $(\alpha/2)^{th}$ and *k* $(1-(\alpha/2)^{th}$ bias-corrected versions. Relying on the values of lower and upper points of intervals, significant mediation can be deduced if the range of these values does not include zero (i.e. both values take the same sign). In addition, pairwise contrast of the two indirect effects that checks if they are equal in size is performed considering the indirect effects of independent variables on a dependent variable through supply chain visibility and performance as the study's key mediators. The contrast of indirect effects is calculated after each bootstrap resample and the new contrast sampling distribution is developed. Following the same statistical logic, significant contrast of indirect effects is deduced when the lower and upper limits of CIs are significantly different from zero.

In this study, five multiple-mediation relationships have been tested. The findings of each mediation analysis are illustrated in the following sections.

<u>Mediation effect between asset management capability and SCA (H. 5+7)</u>

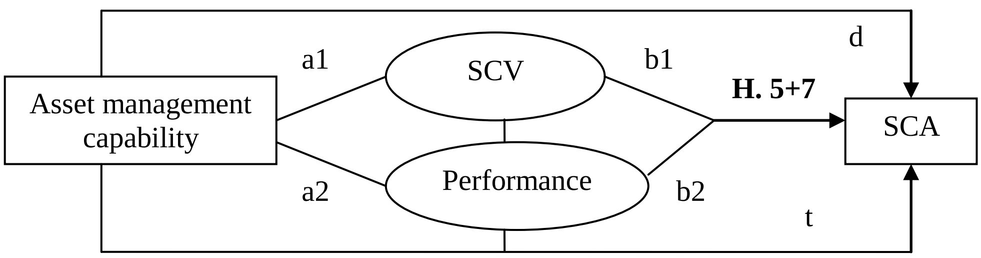


Figure 6-16: Hypothesis H. 5+7

Hypothesis [5+7] states that SCV and firm's performance mediates the relationship between asset management capability and SCA. This hypothesis postulates that SCV and firm's performance constitute the underlying mechanisms through which asset management capability may influence SCA. This means that the effect of asset management capability on SCA is indirect as it is mediated through SCV and firm's performance.

Here, the mediation model tests the mediation impact of asset management capability on SCA through SCV and performance as proposed mediators. The following table introduces the outcome of bootstrap mediation analysis.

Table 6-8: The mediation effect between asset management capability and SCA

	SCV (M1)		Performance (M2)		SCA (DV)	
	β	*t*	β	*t*	B	*t*
Direct effect of (IV)	.370	3.27**	.153	2.85**	-.04	-.51
SCV (M1)					.39	2.99**
Performance (M2)					.51	1.85
Total effect of (IV)					.18	1.91
Firm size (C)					-.99	-.83
Industry type1 (C)					-4.9	-.77
Industry type2 (C)					-3.7	-.65
Industry type3 (C)					1.79	.24
Industry type4 (C)					-2.6	-.42
Model summary of SCA (DV): R^2: .57***; Adjusted R^2: .50; Overall model *F*: 7.83***						
**p*< .05, ***p*< .01, ****p*< .001						
DV: dependent variable, IV: independent variable, M1, M2: mediators, C: control						

Bootstrap Indirect effect of Asset Management capability on SCA						
	Data	Boot	Bias	SE	BC-CIs	
					Lower	Upper
Total	.221	.227	.005	.079	.079	.388
SCV	.144	.151	.007	.069	.039	.306
Performance	.078	.076	-.002	.059	-.006	.243
C1	.067	.075	.009	.101	-.127	.277

Note: CB-CIs, bias corrected confidence intervals; 5000 bootstrap samples.

The bootstrap results illustrated here is based on 5000 bootstrap samples. Table 6-8 illustrates that the model significantly explains 57% (R^2= .57) of the variance in SCA through the indirect effects of asset management capability. The results show a significant positive relationship between asset management capability and the two mediators i.e. SCV and performance (paths a1, a2), (β= .37, p< .01, β= .15, p< .01, respectively). The results also indicate non-significant effect of control variables on the dependent variable i.e. SCA. Table 6-8 illustrates the total (path t) and direct (path d) effects of asset management capability on SCA are not significant (β= .18, p> .05, β= .04, p> .05, respectively). The difference between total (path t) and direct effects (path d) is total indirect effect of the two proposed mediators with a point estimate of .221 and a 95% BC bootstrap CI of .079 to .388. This indicates that the difference between the total and the direct effect of asset management capability on SCA is different from zero. As such, this result proves that SCV and firm's performance significantly mediate the effect of asset management capability on SCA.

Table 6-8 shows that the directions of the a*i* and b*i* paths are positive (a1: β= +.370, b1: β= +.39, a2: β= +.153, b2: β= +.51). In other words, they are consistent with the interpretation that better asset management capability leads to better SCV and better performance, which in turn leads to enhanced SCA. This result proves the research hypothesis that asset management capability is positively affect SCA through the underlying mechanisms of SCV and firm performance.

In considering the specific indirect effect of each mediator, only supply chain visibility is a significant mediator because its lower and upper points of 95% BC bootstrap CI does not include zero (.039, .306, respectively). The firm's performance does not contribute significantly to the indirect effect of this mediation relationship due to the inclusion of zero within its lower and upper limits of 95% CI (-.01 to .24). These findings indicate that SCV is a significant individual mediator between asset management capability and SCA, whereas performance is not. In addition, the multiple indirect effect of both SCV and performance is confirmed to be significant between asset management capability and SCA. This proves that both mediators should work together to contribute significantly to this indirect relationship. With regard to the pairwise contrast (C1), table 6-8 indicates that no specific indirect effect is significantly larger than the other, with BC 95% CI of -.1265 to .2771.

<u>Mediation effect between IT infrastructure and SCA (H. 6)</u>

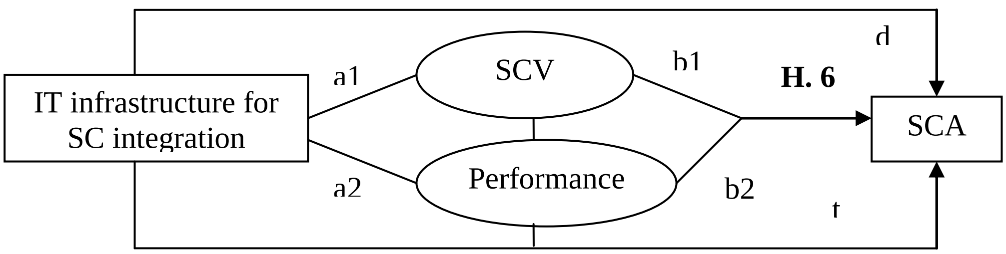


Figure 6-17: Hypothesis H.6

Hypothesis [6] posits that SCV and firm's performance mediates the relationship between IT infrastructure for supply chain integration and SCA. Put it in another way, the effect of IT infrastructure capability on SCA is indirect in that it is constituted through the underlying mechanisms of both SCV and firm performance, respectively. Here, bootstrap tests examine the indirect effect of IT infrastructure for supply chain integration capability on SCA through the two mediators i.e. SCV and performance. The following table provides the output of the mediation test.

Table 6-9: The mediation effect between IT infrastructure capability and SCA

	SCV (M1)		Performance (M2)		SCA (DV)	
	β	*t*	β	*t*	B	*T*
Direct effect of (IV)	1.26	6.50***	.41	3.92**	.24	1.31
SCV (M1)					.29	2.16*
Performance (M2)					.49	1.97
Total effect of (IV)					.82	4.86***
Firm size (C)					-1.24	-1.14
Industry type1 (C)					-4.88	-.81
Industry type2 (C)					-3.50	-.66
Industry type3 (C)					1.07	.16
Industry type4 (C)					-2.74	-.49
Model summary of SCA (DV): R^2: .59***; Adjusted R^2: .52; Overall model *F*: 9.11***						
*p< .05, **p< .01, ***p< .001						
DV: dependent variable, IV: independent variable, M1, M2: mediators, C: control						

Bootstrap Indirect effect of IT infrastructure capability on SCA						
	Data	Boot	Bias	SE	BC-CIs	
					Lower	Upper
Total	.574	.563	-.011	.168	.304	.993
SCV	.371	.364	-.007	.173	.050	.738
Performance	.204	.199	-.004	.124	.009	.506
C1	.167	.164	-.003	.249	-.349	.665

Note SE, standard error; CB-CIs, bias corrected confidence intervals; 5000 bootstrap samples.

The results indicate that the model significantly explains 59% (R^2= .57) of the variance in SCA as the criterion variable through the indirect effects of IT infrastructure for supply chain integration. As seen in table 6-9, IT infrastructure for supply chain integration capability significantly affects SCV and performance as the two mediators (paths a1, a2), (β= 1.26, p< .001, β= .41, p< .01, respectively). With regard to control variables, none of them has a significant impact on SCA as the criterion variable. The results also confirm a non-significant relationship between the direct effect (path d) of IT infrastructure capability and SCA whilst a significant effect of the total effect (path t) of this capability on SCA as the dependent variable (β= .24, p> .05, β= .82, p< .001, respectively) was proved. The difference between the total and direct effects represents the total indirect effect of the two proposed mediators i.e. SCV and performance with a point estimate of .574 and a 95% BC bootstrap CI of .304 to 0.993. This indicates that the difference between the total and the direct effect of IT infrastructure capability on SCA is different from zero. This result confirms a significant mediation relationship between IT infrastructure capability and SCA through SCV and firm's performance. To decide about the direction of this relationship, table 6-9 illustrates that the directions of the a*i* and b*i* paths are positive (a1: β= +.1.26, b1: β= +.29, a2: β= +.41, b2: β= +.49). Positive directions of a*i* and b*i* paths provide an interpretation that better IT infrastructure capability leads to better SCV and better performance, which in turn leads to enhanced SCA that proves the associated research hypothesis [H. 6].

In considering the specific indirect effect of SCV and performance as individual mediators, the results revealed that for both SCV and performance the lower and upper points of 95% BC bootstrap CI does not include zero (.050-.738, .009-.506, respectively). This finding proves that supply chain visibility and performance are significant individual mediators of the effect of IT infrastructure capability on SCA. This means that both SCV and performance work significantly as individual mediators as well as multiple mediators between IT infrastructure for supply chain integration and SCA. In line with the hypotheses developed, this study is only interested in multiple mediation effects. With regard to pairwise contrast (C1), table 6-9 indicates that no specific indirect effect is significantly larger than the other, with BC 95% CI of -.349 to .665.

<u>Mediation effect between SC process integration and SCA (H. 8a)</u>

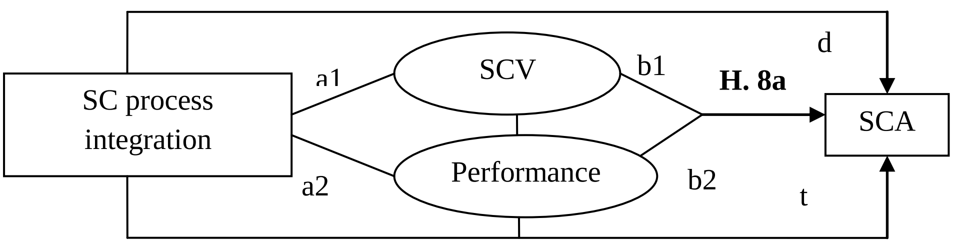


Figure 6-18: Hypothesis H. 8a

Hypothesis [8a] posits that SCV and firm's performance mediates the relationship between supply chain process integration and SCA. This means that the influence of supply chain process integration capability on SCA is indirect and constituted through the direct effect of this capability on SCV and performance that, in turn directly affect SCA. This hypothesis was investigated using bootstrap mediation test presented in table 6-10.

Table 6-10: The mediation effect between SC process integration and SCA

	SCV (M1)		Performance (M2)		SCA (DV)	
	β	*t*	β	*t*	B	*t*
Direct effect of (IV)	1.66	10.6***	.66	7.69***	.44	1.66
SCV (M1)					.21	.16
Performance (M2)					.45	1.69
Total effect of (IV)					1.09	7.09***
Firm size (C)					-2.03	-1.69
Industry type1 (C)					-4.65	-.74
Industry type2 (C)					-3.60	-.67
Industry type3 (C)					1.59	.23
Industry type4 (C)					-1.30	-.23
Model summary of SCA (DV): R^2: .61***; Adjusted R^2: .55; Overall model *F*: 9.39***						
**p*< .05, ***p*< .01, ****p*< .001						
DV: dependent variable, IV: independent variable, M1, M2: mediators, C: control						

Bootstrap Indirect effect of SC process integration capability on SCA

	Data	Boot	Bias	SE	BC-CIs	
					Lower	Upper
Total	.648	.627	-.021	.274	.127	1.232
SCV	.350	.341	-.009	.290	-.279	.881
Performance	.298	.286	-.012	.191	-.047	.717
C1	.051	.055	.004	.407	-.732	.866

Note: SE, standard error; CB-CIs, bias corrected confidence intervals; 5000 bootstrap samples.

The results indicate that the model significantly explains 61% (R^2: .61) of the variance in SCA through the indirect effects of supply chain process integration. The results introduced in table 6-10 illustrate that supply chain process integration significantly explains the variance in the two mediators including SCV and performance, (paths a1, a2), (β= 1.66, p< .001, β= .66, p< .001, respectively). None of the control variables shows any significant effect on the dependent variable i.e. SCA. In addition, a non-significant direct effect (path d) of supply chain process integration on SCA was proved. This means that supply chain process integration has no impact on SCA when it is introduced as a sole variable in the model. The results confirm that the total effect (path t) of supply chain process integration significantly explains the variance in SCA, (β= 1.09, p< .001). The difference between total (path t) and direct (path d) is the total indirect effect of the two proposed mediators i.e. SCV and performance with a point estimate of .648 and a 95% BC bootstrap CI of .127 to 1.232. Therefore, the total indirect effect of supply chain process integration is significant i.e. it is different from zero. In other words, SCV and firm's performance significantly mediate the effect of supply chain integration on SCA. In reference to the direction of the mediation effect, table 6-10 shows that the directions of the a*i* and b*i* paths are positive (a1: β= +.1.66, b1: β= +.21, a2: β= +.66, b2: β= +.45). This finding proves that improving supply chain process integration leads to better SCV and better performance that in turn leads to better SCA, providing support for the related hypothesis [H. 8a].

In relation to the specific indirect effect of SCV and performance as individual mediators, the results indicates the inclusion of zero for both SCV and performance within the lower and upper points of 95% BC bootstrap CI, -.279 to .881, -.047 to .717, respectively). This finding proves that supply chain visibility and performance are not significant individual mediators of the effect of supply chain process integration on SCA, i.e. they have to work together to contribute significantly to such effect. With regard to pairwise contrast (C1), table 6-10 indicates that no specific indirect effect is significantly larger than the other, with BC 95% CI of -.732 to .866.

<u>Mediation effect between focal firm-3PL relationship and SCA (H. 8b)</u>

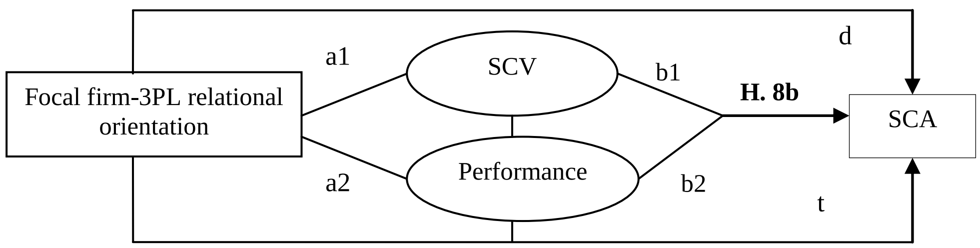


Figure 6-19: Hypothesis H. 8b

Hypothesis [8b] suggests that focal firm-3PL relational orientation capability positively influences SCA through the positive effect of the former on SCV and performance. This means that the effect of focal firm-3PL relational orientation capability on SCA is indirect as it is mediated through SCV and performance. The results of the investigation of this hypothesis relying on bootstrap mediation test are presented in the following table 6-11.

Table 6-11: The Mediation effect between focal firm-3PL relationship and SCA

	SCV (M1)		Performance (M2)		SCA (DV)	
	β	*t*	β	*t*	B	*t*
Direct effect of (IV)	.53	3.35**	.21	2.82**	.01	.14
SCV (M1)					.32	2.58*
Performance (M2)					.52	2.03*
Total effect of (IV)					.30	2.40*
Firm size (C)					-1.54	-1.26
Industry type1 (C)					-3.98	-.65
Industry type2 (C)					-3.33	-.62
Industry type3 (C)					3.65	.52
Industry type4 (C)					-.933	-.16
Model summary of SCA (DV): R^2: .57***; Adjusted R^2: .49; Overall model *F*: 7.49***						
**p*< .05, ***p*< .01, ****p*< .001						
DV: dependent variable, IV: independent variable, M1, M2: mediators, C: control						

Bootstrap Indirect effect of 3PL relational orientation capability on SCA						
	Data	Boot	Bias	SE	BC-CIs	
					Lower	Upper
Total	.282	.270	-.013	.096	.115	.495
SCV	.170	.163	-.007	.081	.045	.367
Performance	.112	.107	-.005	.075	.002	.318
C1	.058	.056	-.002	.122	-.181	.315

Note: SE, standard error; CB-CIs, bias corrected confidence intervals; 5000 bootstrap samples.

The results revealed that the model significantly interprets 57% (R^2= .57) of the variance in SCA through the indirect effects of the focal firm-3PL relational orientation capability. As shown in table 6-11, focal firm-3PL relational orientation capability significantly predicts both SCV and performance as the key mediators, (paths a1, a2), (β= .53, p< .01, β= .21, p< .01, respectively). The results confirm a non-significant effect of all control variables on SCA as a dependent variable. The same non-significant relationship is proved between the direct effect (path d) of 3PL relational orientation capability and SCA (β= .01, p> .05). On the other hand, the total effect (path t) of focal firm-3PL relational orientation capability, that considers both direct and indirect effects (path d and path a x b), is positively explains the variance in SCA (β= .30, p< .05). The difference between total and direct effects is total indirect effect of the two proposed mediators with a point estimate of .282 and a 95% BC bootstrap CI of .115 to .495. This proves that the difference between the total and the direct effect of focal firm-3PL relational orientation capability on SCA is different from zero. This result assures that SCV and firm's performance significantly mediate the effect of focal firm-3PL relational orientation capability on SCA. As illustrated in table 6-11, the directions of the a*i* and b*i* paths are positive (a1: β= +.53, b1: β= +.32, a2: β= +.21, b2: β= +.52). This finding provide a proof that improving focal firm-3PL relational capability affects positively SCV and firm performance that in turn enhances SCA. As such, the related research hypothesis [H.8b] has been accepted i.e. 3PL associated capability significantly justifies a positive impact on SCA that is mediated by SCV and performance.

In respect to the specific indirect effect of individual mediators, both SCV and performance are significant individual mediators as the lower and upper points of 95% BC bootstrap CI does not include zero (.045-.367, .002-.318, respectively). This result means that SCV as well as performance work as individual mediators for the effect between focal firm-3PL relational orientation capability and SCA. The same variables work together as significant multiple mediators between focal firm-3PL relational orientation and SCA. According to the hypothesised relationships developed, the study main concern is multiple indirect effects. In related to pairwise contrast (C1), table 6-11 confirms no significant difference between the two specific indirect effect of SCV and performance i.e. no effect is significantly greater than the other (BC 95% CI of -.181-.315.

Mediation effect between internal integration and SCA (H. 8c)

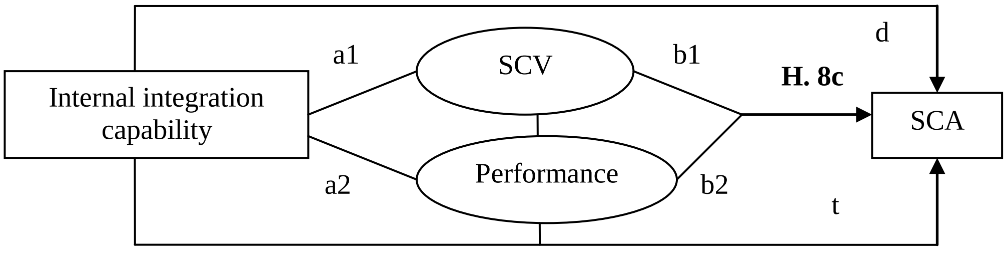


Figure 6-20: Hypothesis H. 8c

Hypothesis [8c] suggests a positive relationship between internal integration capability and SCA that is mediated by SCV and performance. This postulates that SCV and performance form the indirect effect of internal integration capability on SCA. This hypothesis has been examined using bootstrap multiple mediation test that revealed the following outcome depicted in table 6-12.

Table 6-12: The mediation effect between internal integration and SCA

	SCV (M1)		Performance (M2)		SCA (DV)	
	β	*t*	β	*t*	β	*t*
Direct effect of (IV)	2.1	4.47***	1.12	5.65***	-.21	-.57
SCV (M1)					.35	2.87**
Performance (M2)					.60	2.15
Total effect of (IV)					1.18	3.09**
Firm size (C)					-1.30	-1.16
Industry type1 (C)					-3.94	-.64
Industry type2 (C)					-2.68	-.49
Industry type3 (C)					2.22	.32
Industry type4 (C)					-2.38	-.41
Model summary of SCA (DV): R^2: .58***; Adjusted R^2: .51; Overall model *F*: 8.42***						
**p*< .05, ***p*< .01, ****p*< .001						
DV: dependent variable, IV: independent variable, M1, M2: mediators, C: control variable						

Bootstrap Indirect effect of internal integration capability on SCA						
	Data	Boot	Bias	SE	BC-CIs	
					Lower	Upper
Total	1.395	1.366	-.029	.403	.749	2.413
SCV	.717	.704	-.013	.316	.243	1.672
Performance	.678	.662	-.016	.383	.039	1.561
C1	.039	.042	.003	.575	-1.058	1.242

Note: SE, standard error; CB-CIs, bias corrected confidence intervals; 5000 bootstrap samples.

The resulted shown in table 6-12 indicates that the model significantly explain 58% (R^2: .58) of the variance in SCA as the dependent variable through the indirect effects of internal integration capability. In relation to the direct effect of internal integration capability on the two mediators, significant effects have been proved on SCV and performance, (paths a1, a2), (β= 2.05, p< .001, β= 1.12, p< .001, respectively). In contrast, a non-significant direct effect (path d) of internal integration on SCA as the criterion variable has been detected, (β= -.21, p> .05). All of the control variables are non-significant predictors of SCA. With regard to the total effect (path t) of the predictor variable that combines its direct and indirect effects, the total effect of internal integration capability significantly explains the variance in SCA, (β= 1.18, $p< .01$). The results also clarify that the total indirect effect of the two mediators i.e. SCV and performance that represents the difference between the total and direct effect indicates a point estimate of 1.395 and a 95% BC bootstrap CI of .749 to 2.413. This proves the significance of the difference between the total and the direct effect of internal integration capability on SCA as it is different from zero. This finding corroborate a significant multiple mediation effect between internal integration capability and SCA through SCV and firm's performance.

The direction of the mediation relationship is determined based on the directions of the a*i* and b*i* paths. As presented in table 6-12, the directions of the a*i* and b*i* paths are positive (a1: β= +2.05, b1: β= +.35, a2: β= +1.12, b2: β= +.60). Positive directions of mediation relationship proves that better internal integration capability positively influence SCV and firm's performance which, in turn leads to better SCA. This finding confirms the associated research hypothesis (H. 8c).

In reference to the specific indirect effect of SCV and performance as individual mediators, the results confirm that for both SCV and performance the lower and upper points of 95% BC bootstrap CI does not include zero, (.243-1.672, .039-1.561, respectively). This finding proves that supply chain visibility and performance are significant individual mediators of the effect of internal integration capability on SCA. To reiterate, both SCV and performance have proven significant individual indirect effects between internal integration capability and SCA. Analysis also indicate a significant multiple indirect effect between internal integration capability and SCA. The key concern of this study is only the multiple indirect effect, which corresponds to its hypotheses. In considering pairwise contrast (C1), table 6-12 indicates that no specific indirect effect is significantly larger than the other, with BC 95% CI of -1.058 to 1.242.

6.6 Summary of the chapter

This chapter has addressed the measurement tools used in this research. For the purpose of preparing the data for statistical analysis, the chapter has started with a detailed investigation of the data entry and cleaning processes and the associated statistical techniques that were employed mainly for checking missing data, and outliers. For the sake of statistically establishing the measurement construct in this research, exploratory factor analysis was conducted through which various reflective and formative measurement scales were developed and their validity and reliability were established. The chapter has statistically tested the proposed research model and its related hypotheses through two key techniques: standard multiple regression and bootstrap multiple mediation analysis. The results have proven the research model and its associated hypotheses.

The following chapter endeavours to discuss the research findings in relation to the literature and the adopted theory.

Chapter 7: Discussion

7.1 Introduction

This chapter presents the findings of the survey study, which was in turn informed by the pilot study and literature review. The survey focused on testing hypothesised relationships between the asset visibility capabilities of a focal firm and supply chain visibility (SCV). In addition, it examined the relationship between these capabilities and sustainable competitive advantage (SCA). Asset visibility is presented as four key capabilities: (1) core technological capability formed by asset management technological capability; (2) complementary technological capability represented through IT infrastructure for supply chain integration; (3) core non-technological capability including logistics-related capability; and (4) complementary non-technological capability incorporating supply chain process integration, focal firm-3PL relational orientation and internal integration.

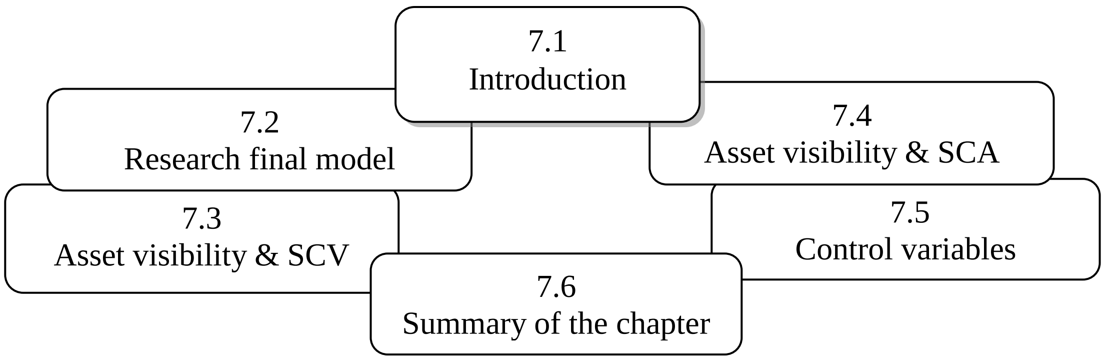


Figure 7-1: Structure of chapter seven

As depicted in figure 7-1, the chapter begins by introducing the final conceptual model informed by the survey findings that will be referred to throughout this chapter. Section 7.3 then discusses the findings of testing the hypothesised relationships between asset visibility capabilities and SCV. Section 7.4 draws on the results of the mediation relationships between asset visibility capabilities and SCA, whilst section 7.5 discusses the findings of the controls used in the study. Finally, section 7.6 provides a summary of the chapter.

7.2 Revised conceptual model and hypotheses

The revised and final conceptual research model illustrating the capabilities associated with asset visibility and their relationship with SCV, performance and SCA is presented in figure 7.2. The initial conceptual model (see figure 2-6, p.47) has been refined based on the survey findings. The four original elements of asset visibility are grouped into six factors (see figure 5-15, p.235), subsequently comprised into three main elements represented through five factors (see figure 7-2). Instead of four key capabilities, three main capabilities of asset visibility have been formed by combining core technological and core non-technological factors into one factor constituting the core capability of asset visibility. The three key capabilities and the related factors are as follows: (1) core capability indicated as asset management capability; (2) complementary technological capability represented through IT infrastructure for supply chain integration; and (3) complementary non-technological capability formed by supply chain process integration, focal firm-3PL relational orientation and internal firm integration. Figure (7-2) exhibits each of these capabilities and their related hypotheses.

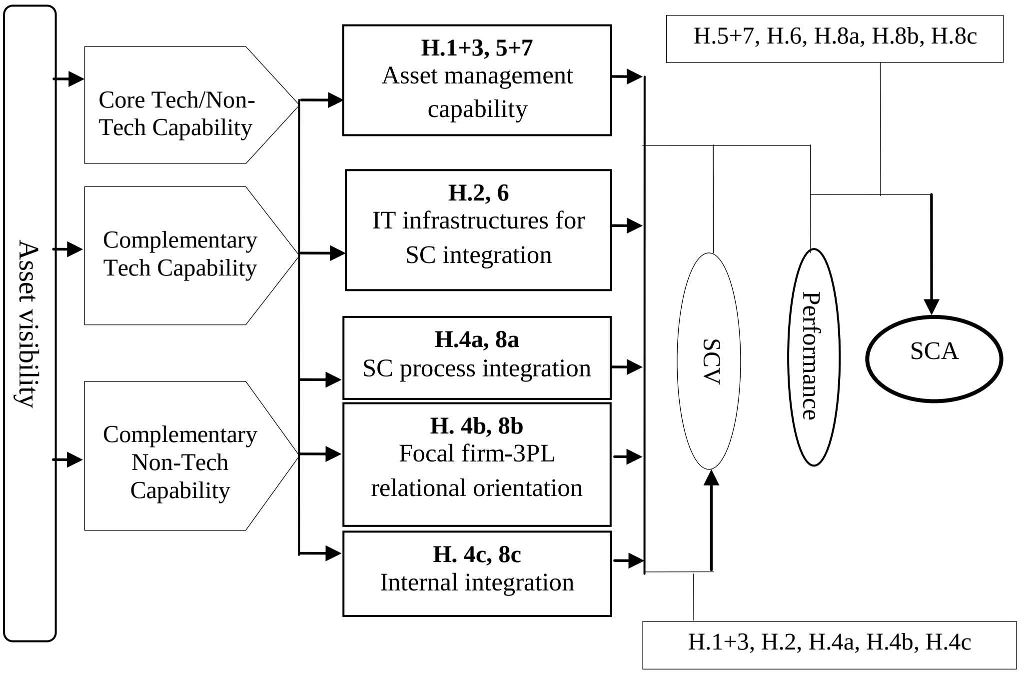


Figure 7-2: Revised model and hypotheses

The following section discusses the findings of testing the relationships between asset visibility capabilities and supply chain visibility.

7.3 Asset visibility capabilities and SCV

This section seeks to answer the research question related to: *How can asset visibility capabilities be used to enhance SCV?* As illustrated in figure 7-2, each of the five factors of asset visibility was regressed against SCV. The survey findings have proven that asset visibility capabilities could significantly predict a substantial percentage (70%) of the variance in supply chain visibility reflecting the magnitude of the predictive power of these factors. In a study of this kind, 70% is a remarkably high percentage. This section provides a detailed discussion of the survey findings relating to each of the five related hypotheses.

7.3.1 Asset management capability and SCV

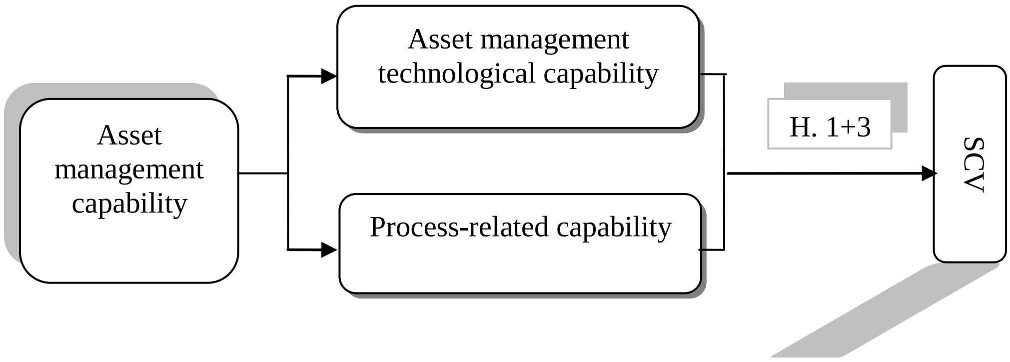


Figure 7-3: Asset management capability and SCV

As shown in figure 7-3, the asset management capability of asset visibility combines both asset management technological capability as a core technological aspect and process-related capability as a core non-technological one. As discussed in chapter 5, core technological capability is conceptualised as *the ability to manage technological resources that are directly linked with asset visibility*. Core non-technological capability is conceptualised as *the ability to manage non-technological resources that are directly linked with asset visibility*. Asset management capability at the RTAs level includes the ability to locate the right assets; to track assets on an individual basis; to identify current physical status in terms of quality; and to maintain historical information about assets, (e.g. Aberdeen-Group, 2004; Johansson & Hellström, 2007; Lampe & Strassner, 2004; Ngai et al., 2007a). This capability is also concerned with the ability to reduce product delivery time as well as RTAs return time; minimise product delivery errors as well as RTAs return errors; maintain efficient consumption of resources; and provide accurate and reliable information about the physical flows (Becker et al., 2009; Ngai et al., 2007a).

The survey results have revealed that asset management capability including core technological and core non-technological aspects is an antecedent for attaining asset visibility. The survey findings have indicated that the asset management capability occupies the second position amongst other capabilities in explaining the variance in asset visibility as 13.8%. Thus, in current supply chains, despite the direct effect of asset management capability on asset visibility, this effect is not sufficient to explain most of the variance in asset visibility compared to a focal firm-3PL relationship as an indirect capability. The survey results have proven a significant correlation between asset management capability and SCV. However, the initial survey findings have illustrated that this capability cannot predict SCV when the impact of other capabilities are involved in the analysis.

The results have also revealed that more than 80% of the cases do not use innovative asset management systems such as RFID-RTAM. Of these, the majority still use manual systems to manage their RTAs, whilst the rest employ barcode systems, see appendix E, p.394. This percentage is in line with literature which indicated that the adoption rate of innovative asset management systems such as RFID is between seven and fifteen percent (Wamba & Chatfield, 2009). This could explain the result regarding the failure of current asset management capability to predict SCV. Current systems relying on manual and barcode tracking may be incapable of ensuring good asset management practice due to their limited technological and process-related capabilities.

The research has conducted further investigation of the relationship between asset management capability and SCV through gauging the sole effect of current asset management capability on SCV (i.e. the effect of other capabilities was controlled for). The finding has indicated the significance of the relationship. In addition, the sole effect of asset management capability on SCV was indirectly measured when testing the relationship between this capability and SCA (see section 7.4.2, p.313). Asset management capability significantly explains 12% of the variance in SCV. Thus, in current supply chains, asset management capability has a similar impact on asset visibility and SCV. This clarifies that current obsolete and traditional asset management systems have limited impact on SCV in terms of the quality of information sharing compared to other asset visibility capabilities. This finding supports the current literature which refers to the negative effect of poor visibility due to flawed asset management systems (Kang & Gershwin, 2005; Ngai et al., 2007a; Raman et al., 2001).

Referring back to the pilot study results and informed by survey findings, innovative asset management systems specifically RFID-RTAM have the capability to enhance SCV depending on their technological and associated logistics capability at an operational level. Hence, this study claims that if innovative asset management systems are adopted that ensure core technological and non-technological capabilities of asset visibility, a substantial positive effect on SCV can be expected.

7.3.2 IT infrastructure for SC integration and SCV

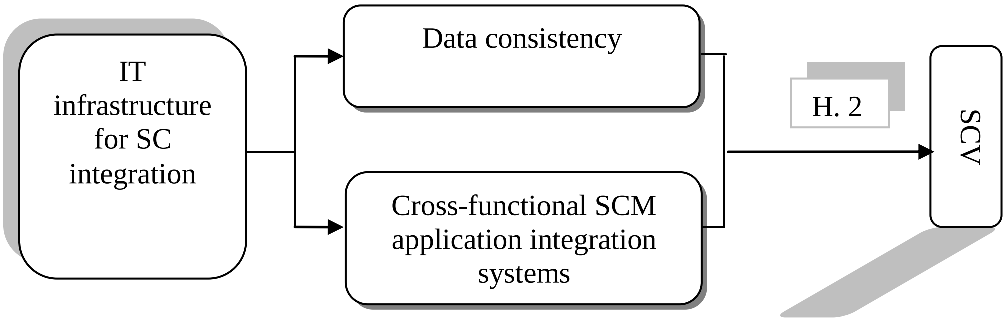


Figure 7-4: IT infrastructure for SC integration and SCV

IT infrastructure for supply chain integration represents a complementary technological capability of asset visibility conceptualised as *the ability to manage technological resources that are indirectly linked with asset visibility.* In this research, IT infrastructure for supply chain integration capability has been measured using two key dimensions: (1) *data consistency*, referring to the degree of consistency in defining and storing data; and (2) *cross-functional SCM application integration systems*, considering the extent to which a focal firm's functional SCM applications are able to communicate and interface in real-time (Angeles, 2009; Malhotra et al., 2005; Rai et al., 2006), see figure 7-4.

The survey results have confirmed that IT infrastructure for supply chain integration is an antecedent capability of asset visibility. IT infrastructure capability occupied the third position amongst other capabilities in explaining the variance in asset visibility. The survey findings have also revealed a significant positive relationship between IT infrastructure for supply chain integration as a complementary technological capability of asset visibility and SCV. This capability could explain 16.9% of the variance in SCV.

These survey findings are congruent with the pilot study and extant literature (e.g. Angeles, 2009; Rai et al., 2006).

IT infrastructure for supply chain integration is seen as a prerequisite for asset management applications where their throughputs are communicated via ICT to other supply chain information applications. Based on the survey analysis, current supply chains exhibit poor asset visibility at an RTA level, partly because of inefficient asset management systems. Therefore, it can be deduced that current IT infrastructure for supply chain integration is constrained at an operational level due to the outmodedness of asset management systems. Given the weak effect of asset management systems on SCV identified in both the survey and pilot studies, the research contends that the contribution of IT infrastructure in SCV could increase upon the introduction of innovative asset management systems such as RFID. The positive relationship between IT infrastructure and SCV refers to the readiness and appropriateness of current supply chain IT infrastructure to absorb and to complement with innovative asset management applications. This is conditioned by simultaneous adoption of these applications based on common standards to ensure IT compatibility. Here, technology cost is a concern that needs to be co-operatively rather than opportunistically negotiated (Klein et al., 2007; Williamson, 1996). Based on the logic of visibility levels developed by the research (see figure 5-7, p.214), the integration between innovative asset management systems such as RFID-RTAM and supply chain IT infrastructure is able to enhance operational-based visibility.

7.3.3 Complementary non-technological capability and SCV

In this research, complementary non-technological capability of asset visibility has been conceptualised as the *ability to manage non-technological resources that are indirectly linked with asset visibility*. Complementary non-technological capability has been grouped into three factors: (1) Supply chain process integration; (2) relational orientation with 3PL; and (3) internal firm integration. In the following sub-sections, the survey findings of each of these related hypotheses are discussed in turn.

7.3.3.1 SC process integration and SCV

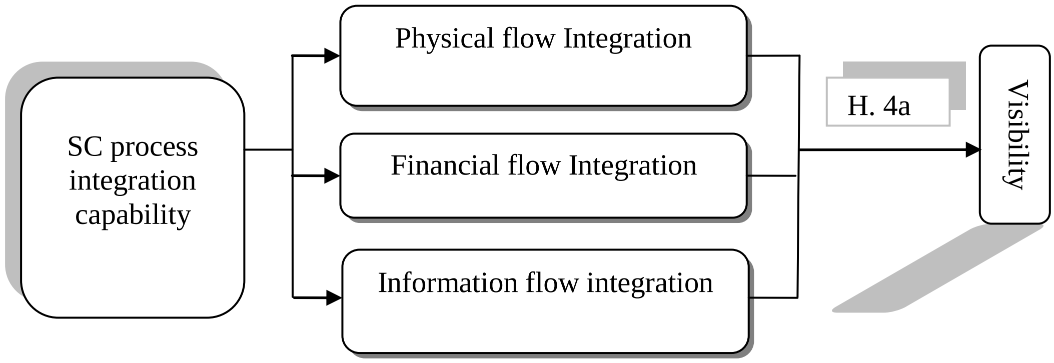


Figure 7-5: SC process integration and SCV

Supply chain process integration is a complementary non-technological capability of asset visibility conceptualised as *the degree to which a focal firm has integrated the flow of information, physical materials, and financial information with its value chain trading partners* (Malhotra et al., 2005; Rai et al., 2006). As illustrated in figure 7-5, SC process integration capability is formed by three key dimensions: (1) *physical flow integration*, indicating the degree to which a focal firm employs global optimisation with its value chain partners to better manage the downstream flow of material and finished products, as well as the upstream flow of empty RTAs and returned products for repair or replacement; (2) *financial flow integration,* referring to the extent to which financial resources exchanged between a focal firm and its trading partners in a supply chain are triggered by workflow events; and (3) *information flow integration,* referring to the degree to which a focal firm shares operational, tactical and strategic information with its supply chain partners (Malhotra et al., 2005; Rai et al., 2006; Sahin & Robinson, 2002).

The survey results have revealed that SC process integration capability is an antecedent for attaining asset visibility. The survey findings have demonstrated a significant positive relationship between SC process integration as a complementary capability of asset visibility and SCV. These research findings are in line with the pilot study findings and associated operations and supply chain literature (e.g. Sahin & Robinson, 2002).

SC process integration capability holds fourth position in explaining the variance in asset visibility. The explanatory power is relatively small compared to other asset visibility capabilities. Conversely, it was the most powerful in predicting changes in SCV (43.4%).

SC process integration capability is triggered by inter-firm relationship mechanisms that were expected to have greater impact on asset visibility. The results have illustrated low correlation between supply chain process integration and asset management capability. Given the outmodedness of the current asset management systems among survey participants, visibility at an operational level seems to be a gap within SCV due to inefficient tracking systems and the associated logistics capability. This is a direct translation of poor physical flow integration which in turn reflects the immaturity of inter-firm relationships at this level. The data analysis confirms that visibility attained within current supply chains is driven mainly by financial flow integration based on order progress rather than the actual flow of products. Variation in orders constrains SCV resulting in poor decision making related to inventory and the production plans of upstream partners. Despite its significant positive relationship with SCV, in current supply chains physical flow integration undermines the overall supply chain process integration. Thus, the contribution of this capability towards SCV is incomplete. Failure to have information flow integration at an operational level has a negative effect on information flow integration at both tactical and strategic levels; thereby, enhancing supply chain process integration entails building good relational and IT infrastructure at all levels.

Combining extant literature, pilot study findings and survey analysis, this study claims that better asset management systems such as RFID-RTAM could enhance asset visibility that is conditioned by certain levels of physical, financial and information flow integration especially at an operational level. Operational-based visibility is the outcome of this integration and is the basis of SCV through facilitation of both tactical and strategic integration (see figure 5-7, p.214).

7.3.3.2 Focal firm-3PL relational orientation and SCV

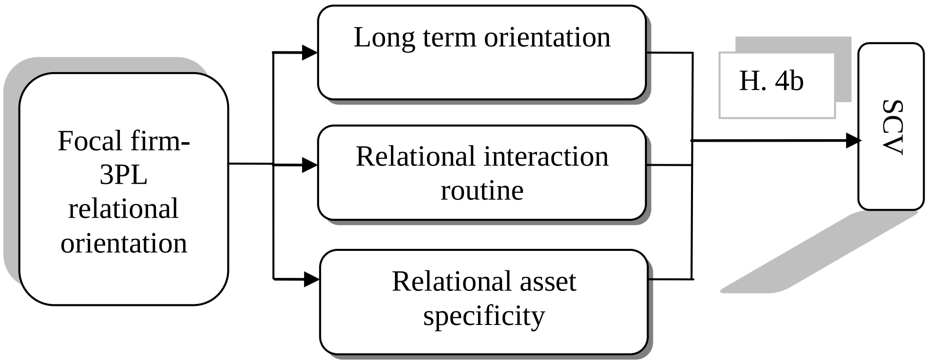


Figure 7-6: Focal firm-3PL relational orientation capability and SCV

In this research, focal firm-3PL relational orientation is a complementary non-technological capability of asset visibility conceptualised as *the extent to which a focal firm's relationship with its 3PL relies on long term orientation, asset-specific investment, and relational interaction routines based on mutual trust and common goals* (Patnayakuni et al., 2006). As depicted in figure 7-6, three key dimensions of focal firm-3PL relational orientation capability has been examined: (1) *long term orientation,* referring to the extent to which a focal firm-3PL relationship is characterised by long-term considerations, mutual benefits and informal governance; (2) *asset specificity,* referring to the extent to which a focal firm's 3PL invests in partner-specific assets, including physical assets and know how; and (3) *relational interaction routines,* representing the extent to which formal and informal arrangements are developed for information sharing and knowledge exchange between a focal firm and its 3PL (Patnayakuni et al., 2006).

The survey results have confirmed that focal firm-3PL relational orientation capability is a prerequisite for attaining asset visibility. The survey findings have confirmed that focal firm-3PL relational orientation as a capability of asset visibility significantly predicts SCV. Focal firm-3PL relational orientation capability explains 15% of the variance in SCV and provides support for the pilot study findings and extant literature (Jayaram & Tan, 2010; Mortensen & Lemoine, 2008). According to the survey results, 3PL is the predominant pattern of logistics service provision (Bhatnagar et al., 1999; Hertz & Alfredsson, 2003; Lai et al., 2008), see appendix D, p.394. Focal firm-3PL relational orientation capability explains almost 30% of the variance in asset visibility, constituting the highest contribution amongst all asset visibility capabilities. Thus, it can be concluded that the current role 3PLs are more influential on asset visibility than on SCV. It appears that the magnitude of the impact of today's focal firm-3PL relational orientation on SCV is constrained by limited asset management capability. This magnitude varies according to the level of integration and collaboration between a focal firm and its 3PL, which is conditioned by the length of the relationship, aligning objectives, mutual benefits and the size of a focal firm's logistics activities (Jayaram & Tan, 2010; Mortensen & Lemoine, 2008).

Based on a combination of literature review, pilot study and survey analysis, this study confirms that focal firm-3PL relational orientation capability is an antecedent for the adoption of better asset management systems such as RFID-RTAM initiative representing asset-specific investment. This initiative may be taken by the 3PLs to improve the service provided considering long term orientation. Simultaneous adoption by a focal firm considering the same standards of the technology as a highly co-operative pattern between the two trading partners maximises the expected outcome. Hence, better asset visibility is expected to lead to enhanced operational-based visibility that in turn may influence visibility at tactical and strategic levels resulting in improved SCV.

7.3.3.3 Internal integration and SCV

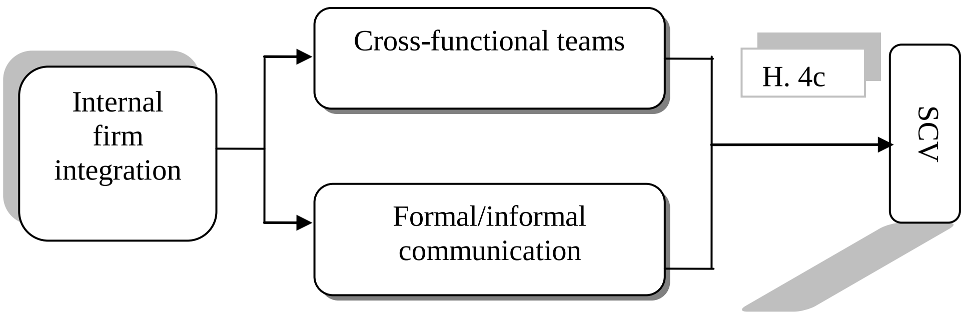


Figure 7-7: Internal integration capability on SCV

In this research, internal firm integration as a complementary non-technological capability of asset visibility have been conceptualised as *the extent to which a focal firm "structures its own organisational strategies, practices and processes into collaborative, synchronised processes, in order to fulfil its customer's requirements"* (Flynn et al., 2010). As presented in figure 7-7, two key dimensions have been used to measure internal integration capability, including cross-functional teams and formal and informal communication channels.

The survey results have confirmed that internal integration capability is an antecedent for both asset visibility and SCV. This capability explains 4.5% of variance in asset visibility and 24.8% of the variance in SCV.

The gap between the influence of the same capability on asset visibility and SCV is stark. This gap appears to reflect the lack of integration at an operational level in two ways. *Firstly,* we can consider a current trend towards outsourcing logistics services. As previously mentioned, obsolete asset management systems undermine focal firm-3PL relational orientation capability to better influence asset visibility. Poor asset visibility is a translation of poor external integration at an operational level that in turn negatively affects internal logistics integration. Thus, in current supply chains, internal integration capability is constrained by inefficient internal logistics integration mechanisms in terms of poor information sharing. *Secondly,* organisations may underestimate or overlook the value of internal integration in attaining SCV. Despite the strong evidence supporting the value-adding role of logistics, many organisations still treat it as a non-core function (Mortensen & Lemoine, 2008).

Reflecting on the pilot study findings and the survey results, the research claims that, considering the five asset visibility capabilities, with the adoption of improved asset management systems better external and internal logistics arrangements are expected. This leads to enhanced operational-based visibility as the foundation of SCV. The following section draws in the discussion of the research findings of the second hypothesised relationship concerned with testing the relationship between asset visibility capabilities and SCA, which is mediated by SCV and firm performance.

7.4 The mediation relationship of asset visibility capabilities on SCA

The study has endeavoured to answer the research question related to how capabilities pertaining with asset visibility can influence sustainable competitive advantage. As illustrated in figure 7-2, each of the five capabilities of asset visibility was regressed against SCA through the mediation effect of both SCV and firm performance. The survey findings have proven that asset visibility capabilities could significantly predict SCA through the mediation effect of SCV and firm performance. This section starts by providing an overview regarding the types of mediation relationships and their implications. It then discusses the findings of each hypothesis.

7.4.1 Mediation relationship: types and implications

In this section, the research draws back on figure 6-15 (p.285) provided within the quantitative analysis chapter to highlight the different types of mediation relationships and their implications. Relying on the study done by Zhao, Lynch Jr., and Chen (2010), figure 7-8 provides a decision tree for mediation relationship types and their implications that will be referred to throughout the following discussion sections.

According to figure 7-8, the significance of the indirect effect (*a*x*b*) of each of the asset visibility capabilities on SCA was checked. If this indirect effect is significant (see the un-shaded part of the figure) then the direct effect associated with specific capability is examined. A non-significant direct effect indicates *only indirect mediation* and confirms the consistency of examined mediator/s with the hypothesised relationship. On the other hand, a significant direct effect requires checking if the total effect including both direct and indirect effect is positive. A positive total effect refers to a complementary mediation relationship whilst negative total effect means that the mediation relationship is 'competitive'. Both *complementary and competitive mediations* indicate that a theoretical framework is incomplete incompletion of adopted theoretical framework. Put another way, the selected mediator/s partially explain the relationship due to the omission of another mediator/s. In the case of non-significant indirect effect (*a*x*b*) (see the shaded part of the figure), the significance of a direct effect of specific capability on SCA is then checked. If the results are significant, this indicates no mediation effect i.e. *only direct effect*. This result confirms that the developed hypothesised relationship is problematic and suggests the inclusion of another mediator/s. Finally, a wrong hypothesised relationship is revealed when a non-significant direct effect illustrates *no-effect* whether direct or indirect.

In the following sub-sections, the research discusses the findings of each of the five hypotheses.

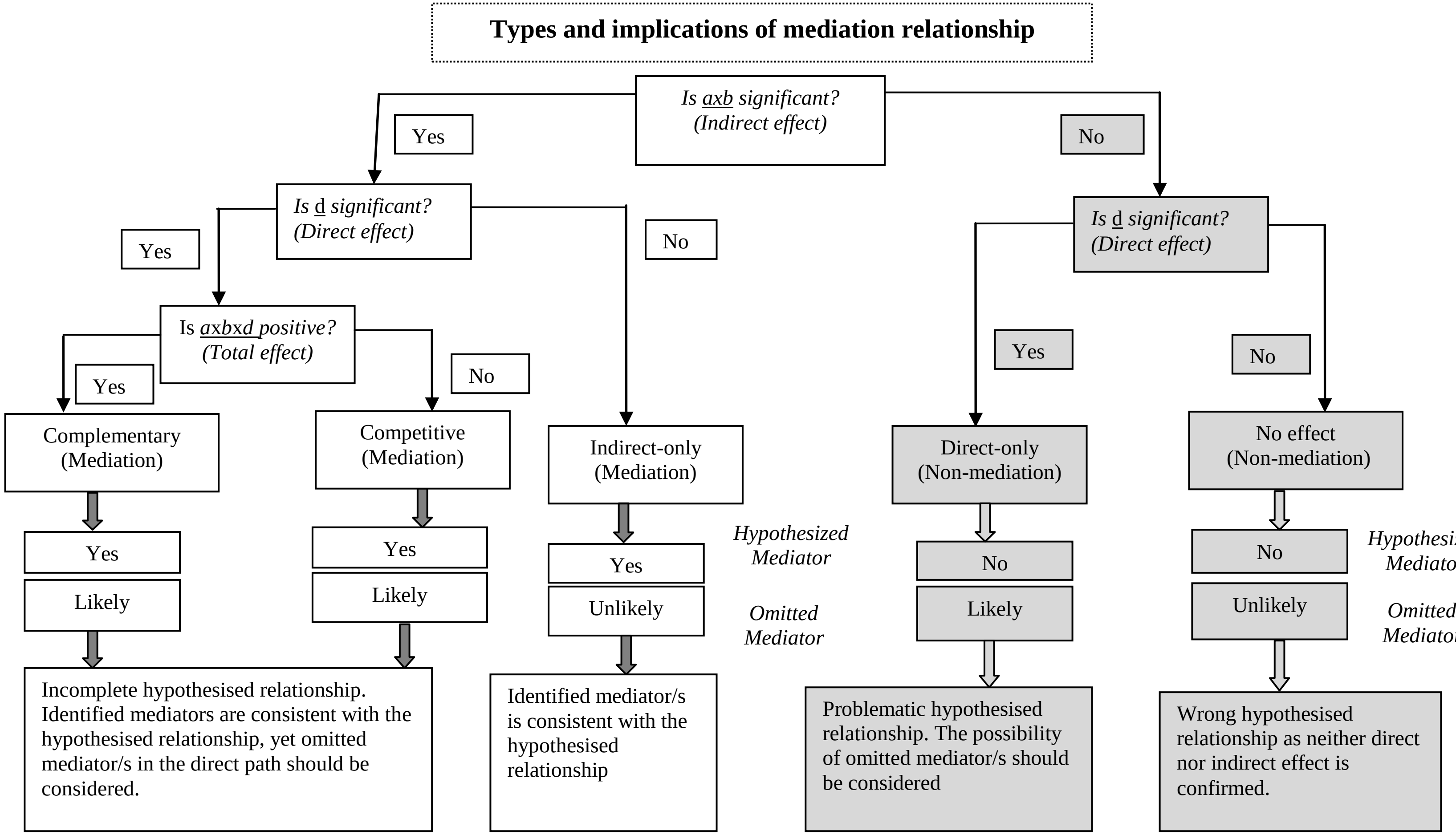


Figure 7-8: Implications of mediation relationship types.

Source: Adapted from (Zhao, Lynch Jr., & Chen, 2010).

7.4.2 The mediation effect of asset management capability on SCA

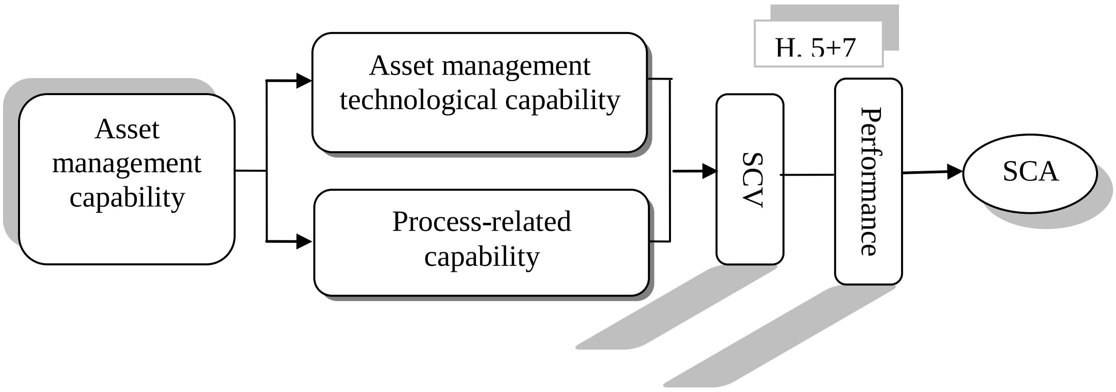


Figure 7-9: Asset management capability on SCA

As depicted in figure 7-9, the research has tested the mediation relationship between asset management capability and SCA, mediated by SCV and performance. As illustrated in figure 7-10, the survey results have illustrated that this capability could significantly predict SCA through the multiple indirect effects of SCV and firm performance. The findings have indicated a positive direction of the mediation relationship i.e. asset management capability positively influence SCA through SCV and performance. This provides an interpretation that better asset management capability results in enhanced visibility and firm performance and in turn leads to SCA.

Although the results have indicated a non-significant direct and total effect (including direct and indirect effects) of asset visibility on SCA, the indirect effect was still significant. Asset management was the only capability amongst other asset visibility capabilities that showed a non-significant total effect on SCA. The magnitude of this indirect effect is relatively small, so that it could not influence the total effect of asset management capability on SCA. Indeed, this finding provides further evidence for the limitation of current asset management capability due to the obsolescence of associated systems. Because the indirect effect of asset management capability was gauged as a sole factor (i.e. the effect of other capabilities was controlled for), this allows the chance for this sole and a relatively limited effect to appear. This was exactly the case when this capability was regressed against SCV as an individual effect, so that their effect became significant. Thus, the results confirm asset management capability do not appear to have a direct effect on SCA.

Based on these results, it can be deduced that the mediation relationship between asset management capability and SCA is only indirect (Powell & Dent-Micallef, 1997; Tyler, 2001), see figure 7-10. This proves that SCV and firm performance as the identified mediators are consistent with the research's hypothesised relationship.

The results have also revealed that asset management capability significantly predicts SCV, previously confirmed through the discussion of the first hypothesised relationship. Similarly, this capability is able to explain the variance in firm performance. SCV driven by enhanced asset visibility is able to improve performance especially at an operational level (see figure 5-7, p.214).

The research findings have indicated that both SCV and firm performance have significant individual, indirect effects between asset management capability and SCA. In other words, SCV as well as firm performance as individual mediators of asset management capability can individually predict SCA. The research argues that such individual indirect effect reflects the case of incomplete or complementary mediation (i.e. the inclusion of both mediators should be considered to provide an overall view of the targeted indirect effect). In addition, the results have revealed that no specific indirect effect is significantly larger than the other. This means that the magnitude of the underlying mechanism of SCV is close in terms of the size of indirect effects to the one related to firm performance through which they can predict the mediation relationship between asset management capability and SCA. This result highlights the consecutive effect of SCV on firm performance as well as the strong association between the two factors.

Although the survey results have confirmed a positive indirect effect of asset management capability on SCA, the research argues that current contribution of this capability is constrained by the lack of core technological capability of asset visibility and can be enhanced by the adoption of innovative asset management systems. In considering the pilot study findings, asset management capability driven by innovative tracking and tracing systems are able to enhance operational performance, as the basis for SCA.

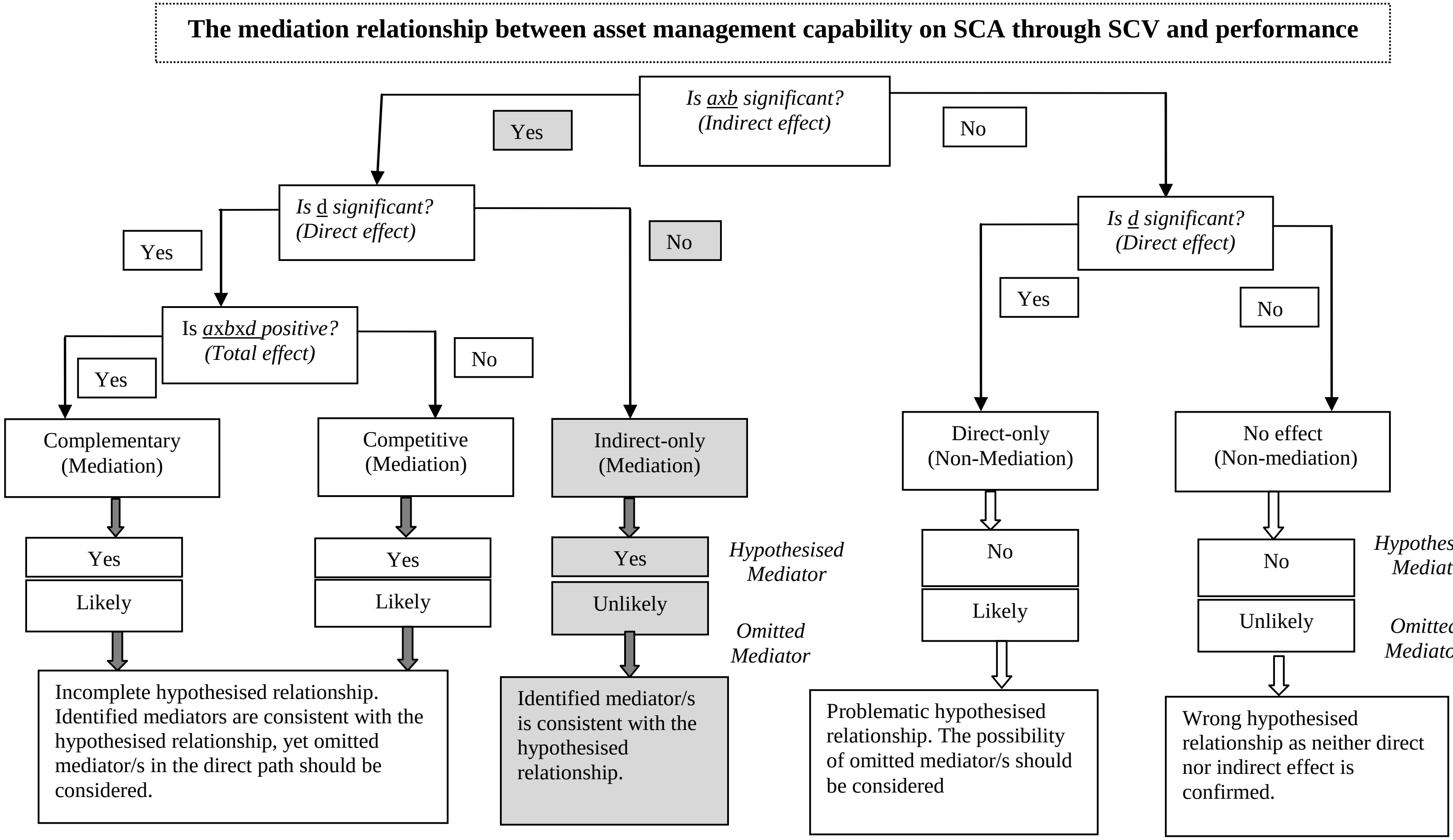


Figure 7-10: Mediation relationship between asset management capability on SCA.

Source: Adapted from (Zhao et al., 2010).

7.4.3 The mediation effect of IT infrastructure for SC integration on SCA

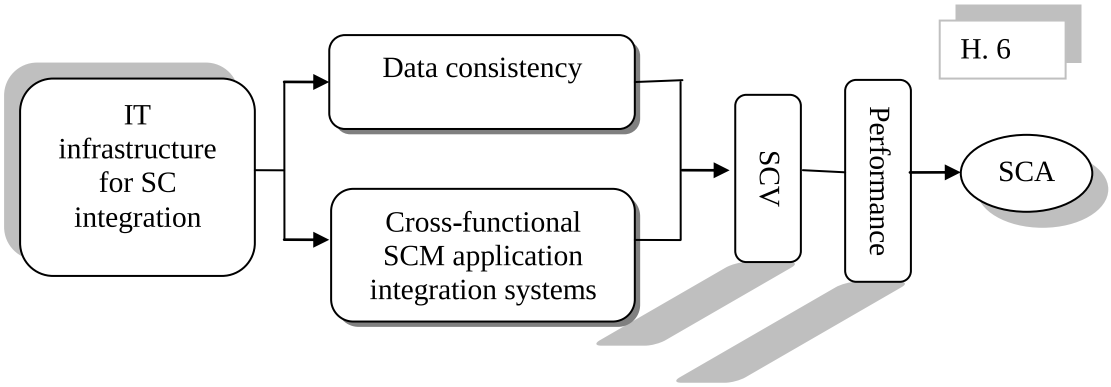


Figure 7-11: IT infrastructure for SC integration and SCA

As illustrated in figure 7-11, the research has investigated the indirect effect of IT infrastructure for supply chain integration, as a complementary technological capability of asset visibility, on SCA through the mediated relationship of both SCV and firm performance. The survey findings have established that the significance of this indirect effect (i.e. the effect of IT infrastructure capability on SCA is indirect in that it is constituted through the underlying mechanisms of both SCV and firm performance). According to these results, it can be concluded that the type of the mediation relationship between IT infrastructure for supply chain integration and SCA is only indirect, see figure 7-12. This proves that SCV and firm performance as the identified mediators are consistent with the research's hypothesised relationship pertaining to the indirect effect of IT infrastructure for supply chain integration on SCA (Bhatt & Grover, 2005; Tyler, 2001). The findings have also confirmed a positive direction of this mediation relationship. As such, better IT infrastructure capability leads to better SCV and in turn firm performance through which SCA is attained.

The results also have confirmed the findings associated with the previous hypothesised relationship that IT infrastructure for SC integration could significantly influence improvements in SCV. It can also significantly predict the changes in firm performance in terms of the ability to shorten product delivery cycle time, offer timeliness of after sales service, improve productivity level, etc. These results match the pilot study findings.

The findings prove that SCV and performance are significant individual mediators of the effect of IT infrastructure capability on SCA. This means that the indirect effect between IT infrastructure for supply chain integration and SCA can be obtained separately through SCV or firm performance. However, the study argues that this separate indirect effect is incomplete and could be classified as complementary mediation (i.e. other mediators should be considered). The results have also revealed that no specific indirect effect is significantly larger than the other. This means that the magnitude of underlying mechanism of SCV is close to the one related to firm performance in predicting the mediation relationship between IT infrastructure for supply chain integration and SCA. This result highlights the consecutive effect of SCV on firm performance as well as the strong association between the two factors.

The results have confirmed a non-significant direct effect of IT infrastructure for supply chain integration on SCA. This introduces further proof that this capability only has an indirect effect on SCA, see figure 7-12. On the other hand, a significant total effect combining both direct and indirect effects of IT infrastructure for supply chain integration on SCA has been identified. This highlights that the magnitude of the underlying mechanisms of SCV and firm performance is strong enough to influence the total effect on SCA. This finding demonstrates the integration capability of today's supply chain IT infrastructure. Yet, the research claims that this capability is constrained by inefficient asset management systems. Hence, it can be concluded that there is a gap in current supply chains' IT infrastructure at an operational level. Referring back to the pilot study findings, adopting innovative asset management systems such as RFID-RTAM can support today's supply chain IT infrastructure for better integration especially at an operational level. This in turn would maximise the proven indirect effect of these capability on attaining SCA.

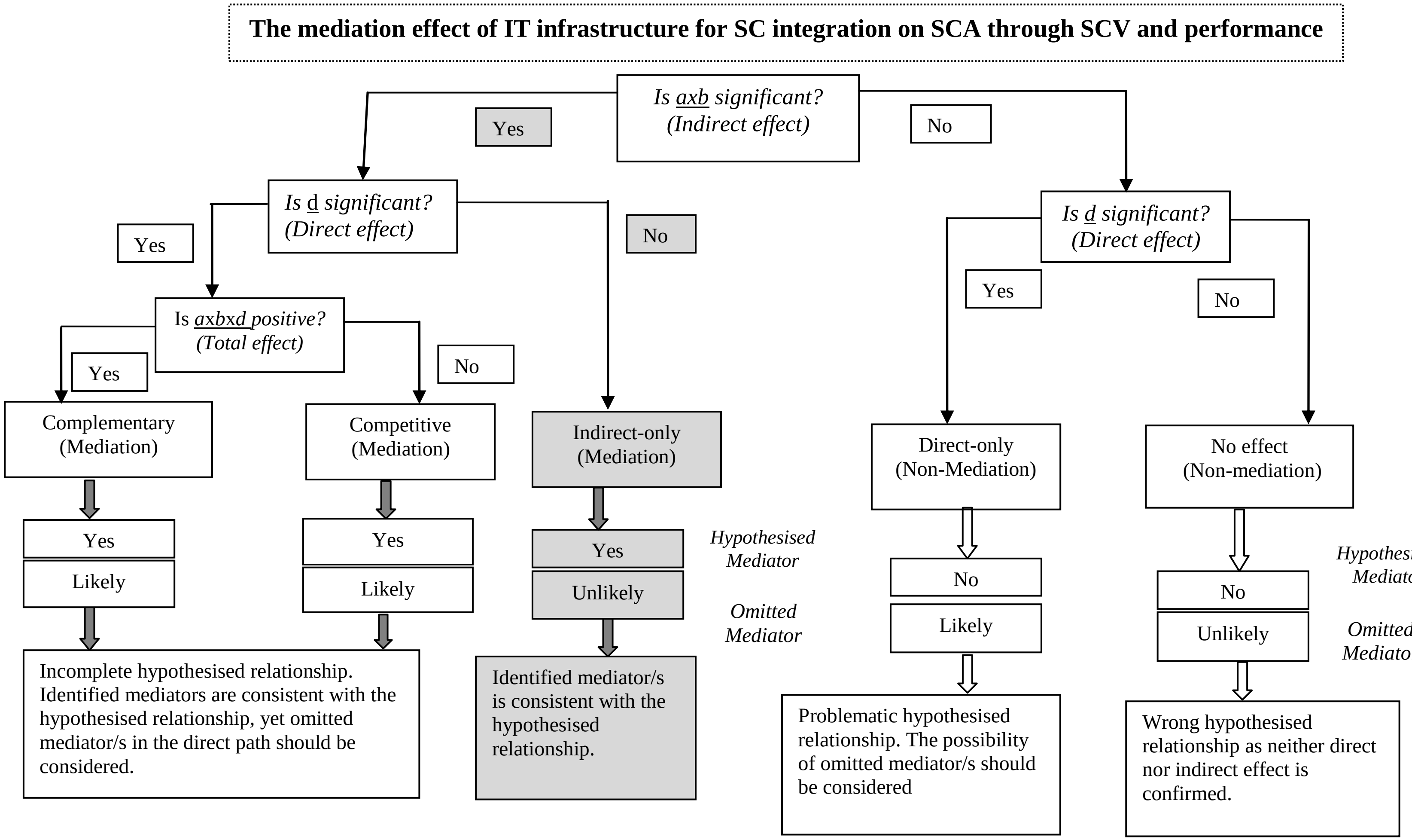


Figure 7-12: Mediation effect between IT infrastructure for SC integration on SCA.

Source: Adapted from (Zhao et al., 2010).

7.4.4 Mediation effect of complementary non-technological capability on SCA

In this section, the research discusses the findings of the mediation relationship between the complementary non-technological capability of asset visibility and SCA. This capability is represented through three sub-capabilities including supply chain process integration; focal firm-3PL relational orientation; and internal firm integration. The mediation relationship relating to each of these three hypotheses is discussed in the following three sub-sections.

7.4.4.1 The mediation effect of SC process integration on SCA

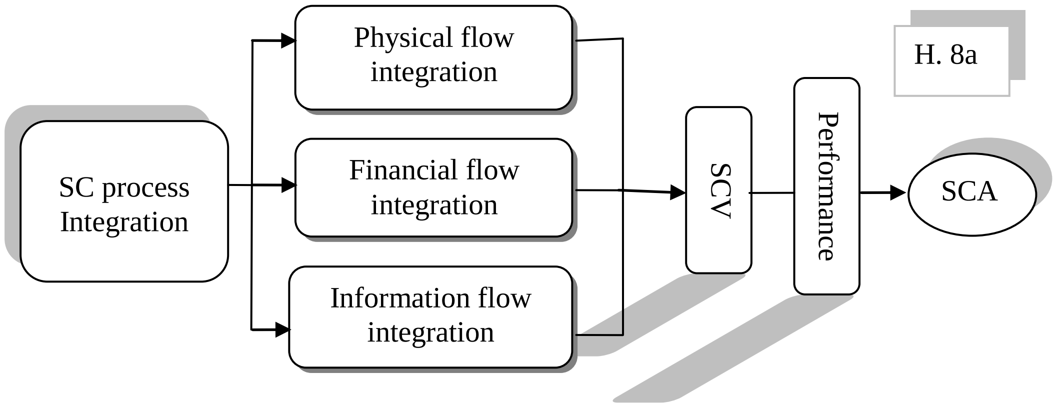


Figure 7-13: SC process integration on SCA

As depicted in figure 7-13 this sub-section discusses the findings of the mediation relationship between SC process integration, as a complementary non-technological capability of asset visibility, and SCA. The research findings have attested the ability of this capability to significantly predict SCA through the indirect effect of both SCV and firm performance. The research findings also confirmed the positive direction of this relationship, meaning that the multiple indirect effect of SCV along with firm performance positively influence the relationship between SC process integration and SCA. Hence, better capability of SC process integration in terms of physical, financial and information flow integration are able to indirectly attain SCA through enhanced SCV and in turn firm performance.

The research findings have also indicated a non-significant direct effect of SC process integration capability on SCA. This confirms that this capability as sole factor cannot directly impact on SCA. This introduces further evidence that the type of the mediation relationship between SC process integration capability and SCA is only indirect, see figure 7-14. This implies that SCV and firm performance, as the identified mediators, are consistent with the research's hypothesised relationship. In addition, the results have substantiated a significant total effect, combining both direct and indirect effects of SC process integration on SCA. In considering the absence of a direct effect, this result provides further proof that SC process integration as a capability of asset visibility has only indirect impact on SCA.

The research findings have confirmed the results of the first hypothesised relationship considering the positive significant impact of SC process integration capability on SCV. The same capability was able to positively and significantly reflect the changes in firm performance on different levels including operational, tactical and strategic. The research argues that the magnitude of current SC process integration can directly affect SCV and performance and indirectly affect SCA is constrained at the physical flow level due to ineffective asset management systems. Physical flow integration is considered a gap within SC process integration as a capability pertaining to asset visibility. Referring back to the pilot study and relevant literature, the employment of enhanced asset management systems such as RFID may improve physical and financial flow integration leading to better operational performance, which is the basis for attaining and sustaining SCA (see figure 5-7, p.214).

The research findings have proven that SCV and performance are not significant individual mediators of the effect of supply chain process integration on SCA. Thus, neither SCV nor firm performance can individually predict the indirect effect of SC process integration on SCA. As such, they have to be accumulated to contribute significantly to the effect. In current supply chains, the magnitude of the two factors is therefore not enough to individually influence SCA. As previously mentioned, such magnitude could improve through better physical flow integration driven by innovative asset management systems.

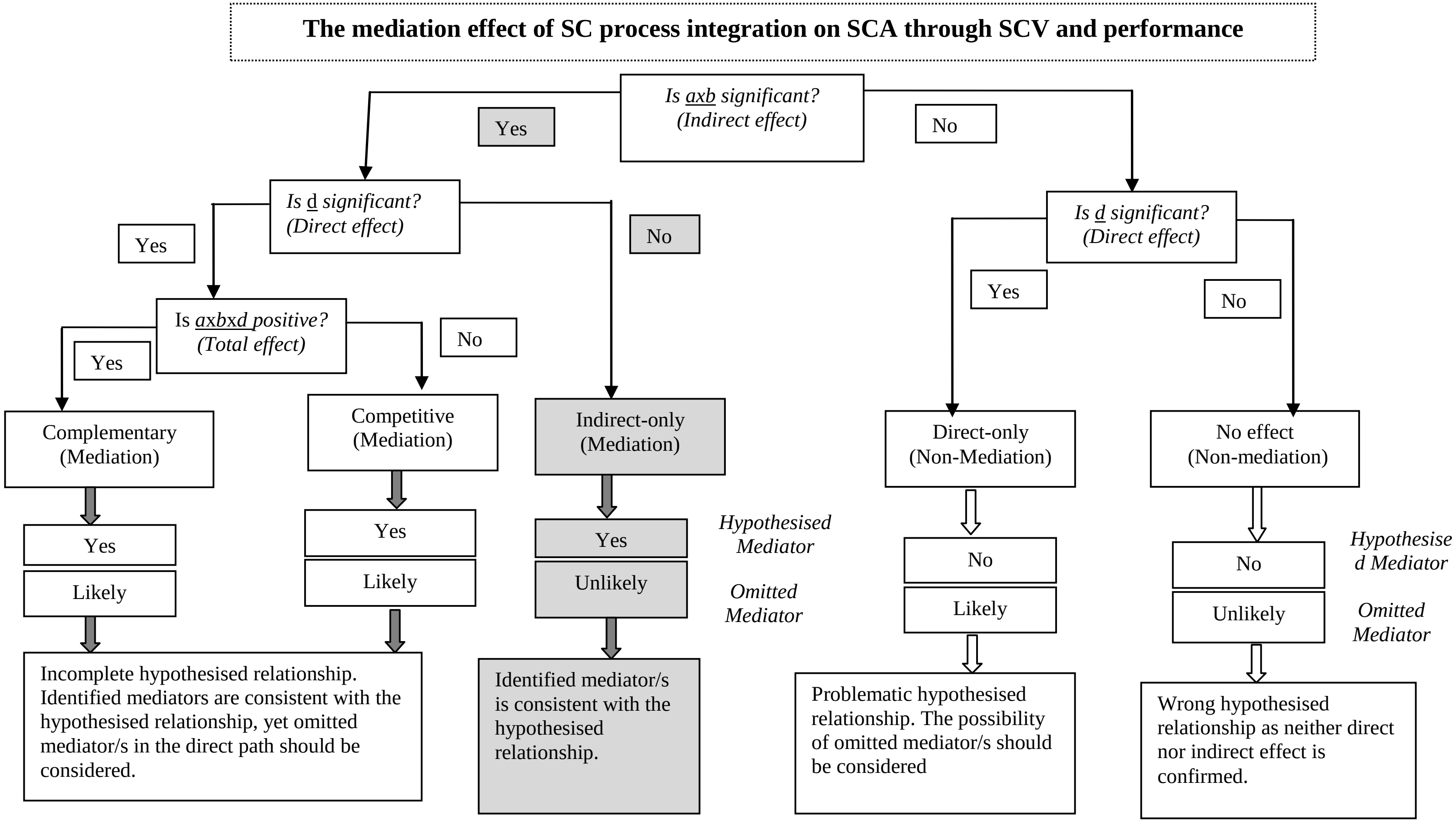


Figure 7-14: Mediation effect between SC process integration on SCA.

Source: Adapted from (Zhao et al., 2010).

The results have also revealed that no specific indirect effect is significantly larger than the other. This means that the magnitude of underlying mechanism of SCV is close to the one related to firm performance in predicting the mediation relationship pertaining to SC process integration and SCA. This result highlights the consecutive effect of SCV on firm performance as well as the strong association between the two factors.

7.4.4.2 The mediation effect of focal firm-3PL relational orientation on SCA

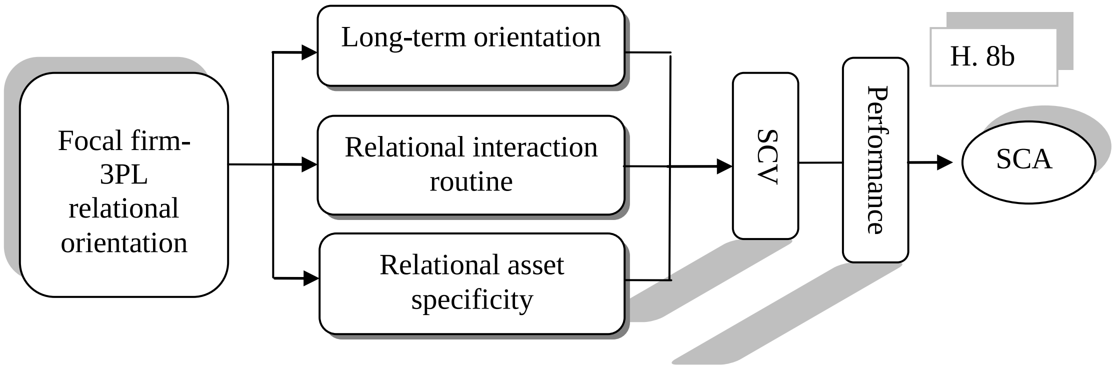


Figure 7-15: Focal firm-3PL relational orientation on SCA

As shown in figure 7-15, this sub-section discusses the findings pertaining to the mediation relationship between focal firm-3PL relational orientation as a complementary non-technological capability of asset visibility and SCA. The research findings have indicated that focal firm-3PL relational orientation significantly influences SCA through the multiple underlying mechanisms of both SCV and firm performance. The results also have confirmed the positive direction of this relationship. That is to say, better focal firm-3PL relational orientation capability, shaped through long-term orientation, relational interaction routine and relational asset specificity, is able to attain SCA through enhanced SCV and in turn performance. These findings are in line with the theoretically developed hypothesised relationship pertaining to the indirect effect of this capability on SCA.

The results indicate a non-significant direct relationship between the focal firm-3PL relational orientation capability and SCA, meaning that the magnitude of the sole effect of this capability is not strong enough to influence SCA and can be classified as indirect only, see figure 7-16. This implies that SCV and firm performance, as the identified mediators, are consistent with the research’s hypothesised relationship. Hence, the effect of focal firm-3PL relational orientation capability can only be translated into SCA through enhanced SCV and in turn firm performance.

The research findings have also confirmed the significance of the total effect, including both direct and indirect effects between focal firm-3PL relational orientation and SCA. In considering the non-significant direct effect, in current supply chains, the impact of SCV along with firm performance is strong enough to make the total effect on SCA significant.

The research findings have proven that SCV and performance are significant individual mediators of the effect of focal firm-3PL relationship on SCA. As such, both SCV and firm performance can individually predict the indirect effect of focal firm-3PL relational orientation on SCA. Similarly, better performance informed by the same capability is capable of influencing SCA. These findings are in line with recent operations and supply chain literature supporting the influential role of 3PLs in managing supply chains (e.g. Jayaram & Tan, 2010; Vaidyanathan, 2005). In addition, the results have shown a non-significant difference between the magnitude of the individual indirect effect of both SCV and firm performance. This confirms the significant contribution of the two factors in the specified mediation relationship.

Although the research has demonstrated a substantial positive contribution towards SCV, firm performance and SCA, there still appears to be gap at the operational logistics level relating to physical flow integration and information sharing caused by traditional asset management systems. The research contends that the magnitude of the indirect effect of focal firm-3PL relational orientation capability on SCA could increase upon the introduction of improved asset management systems such as RFID-RTAM. The key outcome would be enhanced asset visibility that is able to influence SCV and in turn performance in a way that can lead to SCA. A 3PL might adopt innovative RTAM applications as asset-specific investments to enhance and maintain a long-term relationship with a focal firm.

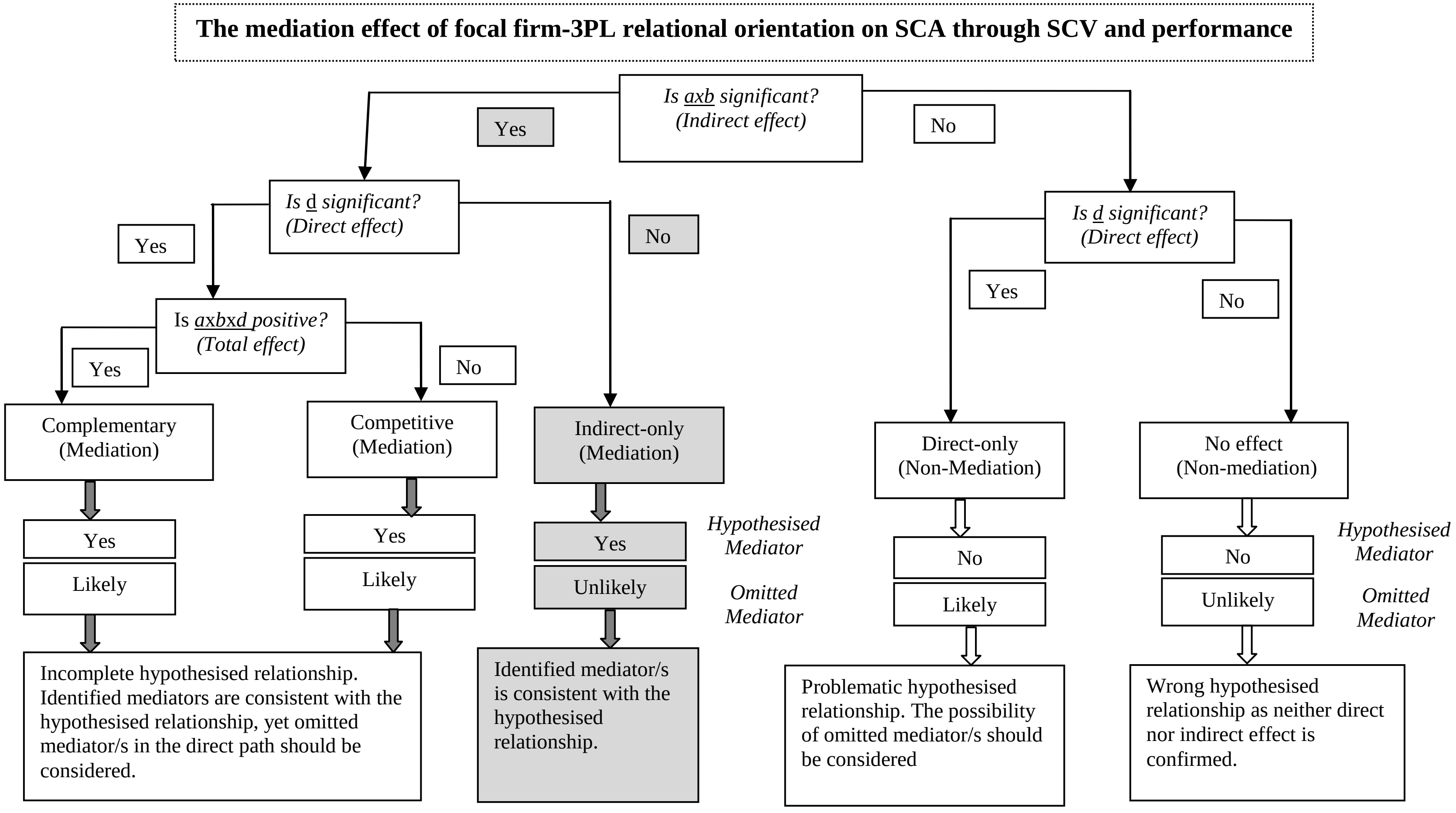


Figure 7-16: Mediation effect between focal firm-3PL relationship on SCA.

Source: Adapted from (Zhao et al., 2010).

7.4.4.3 The mediation effect of internal integration on SCA

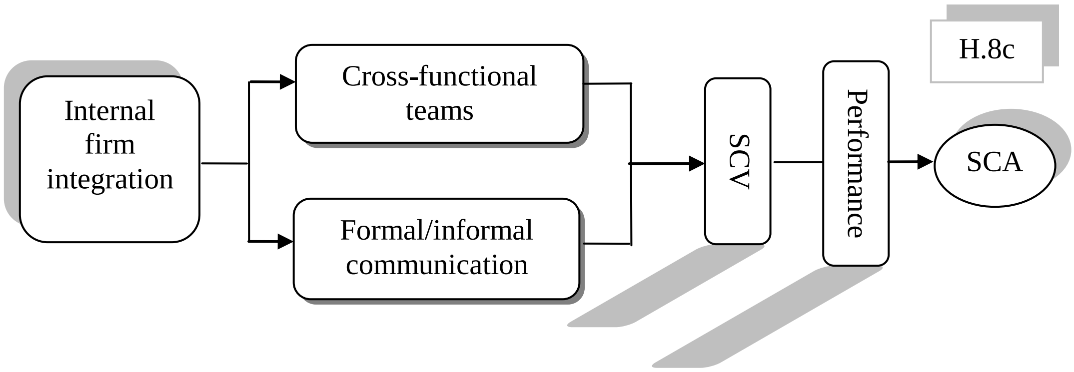


Figure 7-17: Internal firm integration on SCA

This sub-section discusses the findings of the mediation relationship between internal firm integration, as a complementary non-technological capability of asset visibility, and SCA (see figure 7-17). The research findings have confirmed the ability of this capability to significantly influence SCA through the indirect effect of both SCV and firm performance, see figure 7-18. In other words, the underlying mechanism of both SCV and firm performance could explain the relationship between internal firm integration and SCA. The research findings also confirmed the positive direction of this relationship, meaning that the multiple indirect effect of SCV along with firm performance as mediators positively reflect the relationship between internal firm integration and SCA. As such, better capability of internal firm integration, based on cross-functional teams being used to tackle and solve problems, and formal and informal communication, is able to indirectly attain SCA through enhanced SCV and in turn firm performance.

The results have established the significant effect of internal integration on both SCV and performance. The former effect has been previously demonstrated and justified through the discussion of the first hypothetical relationship. The latter effect on performance is in line with the pilot study findings supported by relevant operations and supply chain literature, that confirm a positive effect of internal integration on performance (e.g. Droge et al., 2004; Flynn et al., 2010; Germain & Iyer, 2006; Gimenez & Ventura, 2005; Pagell, 2004; Stank, Keller, & Closs, 2001).

The research findings have indicated the significance of the sole indirect effect of SCV on the relationship between internal integration and SCA. That is to say, currently SCV, driven by enhanced internal integration capability, is able to predict SCA. Similarly, the results have illustrated a significant sole indirect impact of firm performance on the relationship between internal integration and SCA. This finding supports relevant literature indicating that internal integration is more influential compared to external integration in predicting firm performance. Thus, in the current business environment, internal integration capability is mature enough to influence firm performance in a way that might lead to SCA. The results have also shown there is no significant difference between the magnitude of the sole indirect effects of both SCV and performance on SCA through internal integration. Hence, both factors contribute significantly to the specified mediation relationship.

The results have revealed a non-significant direct impact of internal integration capability on SCA, but a significant total direct and indirect impact of this capability on SCA. Hence, the magnitude of the mediation relationship is strong enough to significantly influence the total effect.

As a key dimension of today's competitive differentiation between firms and among supply chains, on-time delivery is driven mainly by both internal and external integration at an operational level. The results have confirmed that in current supply chains, no significant correlation has been detected between internal firm integration and asset management capability. These findings highlight the previously mentioned gap on physical flow level that constrains operational performance and in turn firm performance. Considering literature and data analysis, the research claims that enhancing operational performance, through the adoption of innovative asset management systems, leads to better firm performance, which is then able to transform an internal integration capability into a competence. This competence constitutes competitive advantage. The unknown mechanism of developing internal integration competence is able to sustain competitive advantage. The following section discusses the findings pertaining to control variables used in this study.

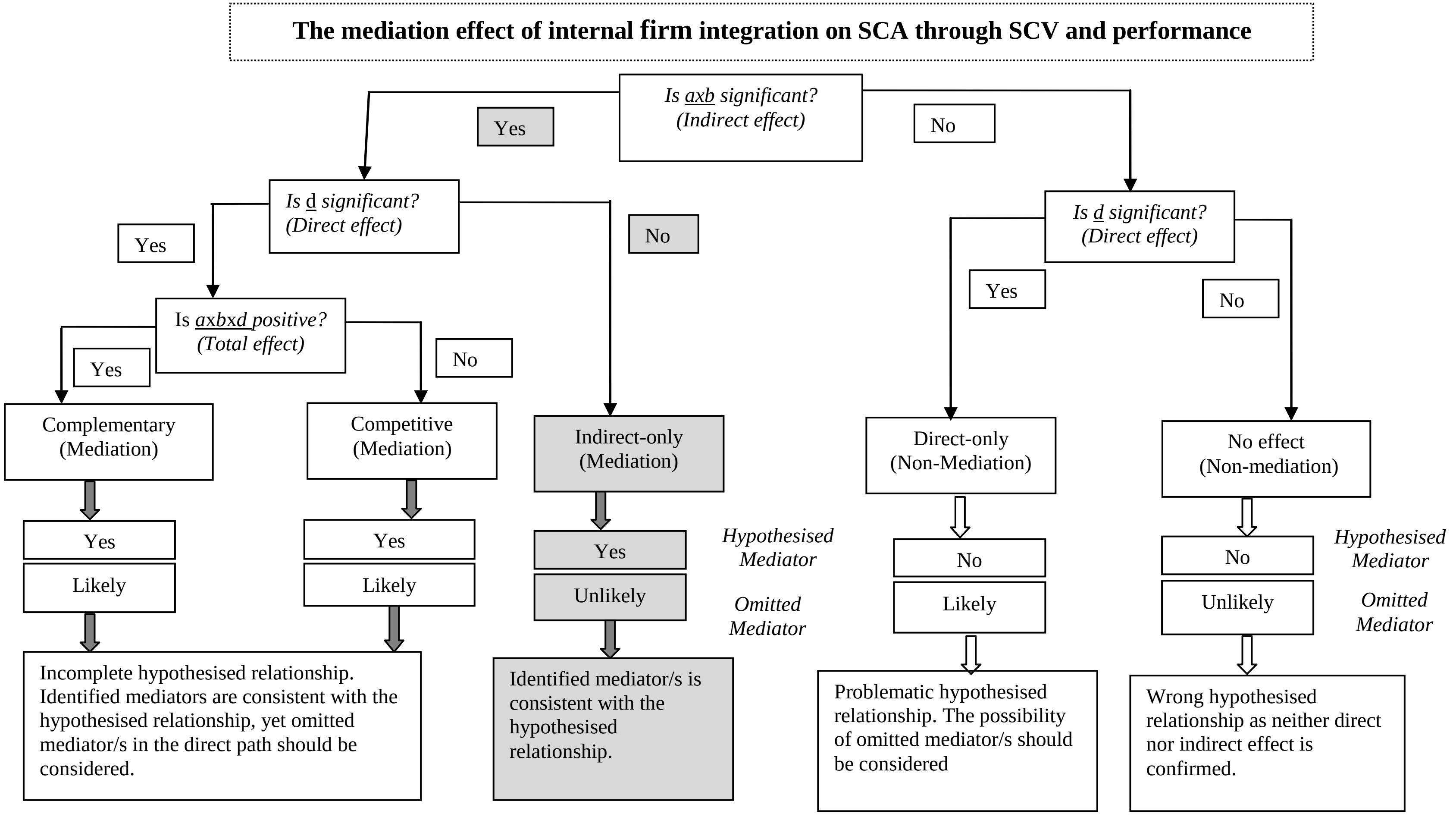


Figure 7-18: Mediation effect between internal firm integration on SCA.

Source: Adapted from (Zhao et al., 2010).

7.5 Control variables

Five main control variables were identified and included in the hypotheses testing to ensure the robustness of the findings. They include firm size, represented through the number of employees and four dummy variables to control for the specific industry effects including: (1) Aerospace, Defence, and Automotive; (2) Healthcare, IT, Telecommunication, Utilities, Mining, and Energy; (3) Logistics, Retail, FMCG (Fast Moving Customer Good); and (4) Other manufacturing firms including electronic, pharmaceutical, chemicals, paper products and general manufacturing.

With respect to the first hypothesised relationship pertaining to the relationship between asset visibility capabilities and SCV, the results have indicated that only firm size has a significant negative effect on SCV. The larger the firm, the lower is the SCV attained. In most cases, large firms deal with a higher volume of products travelling across supply chains compared to small firms

In considering such high volumes along with traditional tracking systems, attaining asset visibility and in turn SCV is challenging, especially when considering the obsolescence of many existing asset management systems.

The research findings have illustrated that none of the industry types influences SCV. Based on a review of operations and supply chain literature, visibility is a common interest between firms and among supply chains and a vital requirement to manage today's supply chains. As such, there is almost no differentiation between industry types. The literature has shown that certain industries have shown more interest in attaining asset visibility such as aerospace, automotive, FMCG, retail, logistics and pharmaceutical (e.g. Baars et al., 2008; Barratt & Oke, 2007; Bottani et al., 2010; Chow, Choy, & Lee, 2007; Zhang et al., 2008). However, this interest coincides with the emergence of innovative asset management systems. As the results highlighted, the percentage of those industries using these advanced systems such as RFID-RTAM, is limited.

In relation to the second set of hypotheses investigating the mediation relationship between asset visibility capabilities and SCA, the results have revealed that none of the control variables were significant in predicting SCA through SCV and firm performance. In other words, neither firm size nor industry types influenced the changes in SCA through the underlying mechanisms of both SCV and firm performance.

7.6 Summary of the chapter

This chapter has provided a discussion of the key findings in relation to the research's hypothesised relationships that endeavoured to answer the research questions guiding this study: *What are the capabilities that constitute managing assets for visibility?; How can these capabilities be used to enhance supply chain visibility?; and How do the capabilities required for visibility impact firm performance and in turn sustainable competitive advantage?* The discussion focused on interpreting the findings of the survey study in the context of the research model developed in chapter five. The refined model was partially informed by the pilot study findings pertaining to the first hypothesised relationship (The relationship between asset visibility capabilities and SCV) along with a theoretical review of operations and supply chain literature associated with the mediation relationship between asset visibility capabilities and SCA through the indirect effect of SCV and firm performance.

The following chapter concludes the study and highlights the theoretical contribution to existing operations and SCM research. In addition, managerial implications and limitations of the research are identified. Finally, suggestions for future research are proposed.

Chapter 8: Conclusions

8.1 Introduction

The main objective of this final chapter is to revisit the research model, objectives and questions. It also draws briefly on the key findings and their managerial, theoretical, methodological and practical implications. Limitations of the research that might affect generalisability are presented. To conclude, recommendations for future research are made.

Figure 8.1 depicts the structure of the chapter. In section 8.2, the chapter begins by revisiting the research model, followed by section 8.3 revisiting the research objectives. Section 8.4 revisits the key questions and how these were answered. Section 8.5 highlights the research implications whilst section 8.6 introduces the research limitations. The recommendations for future research are presented in section 8.7. Section 8.8 is a summary of the chapter.

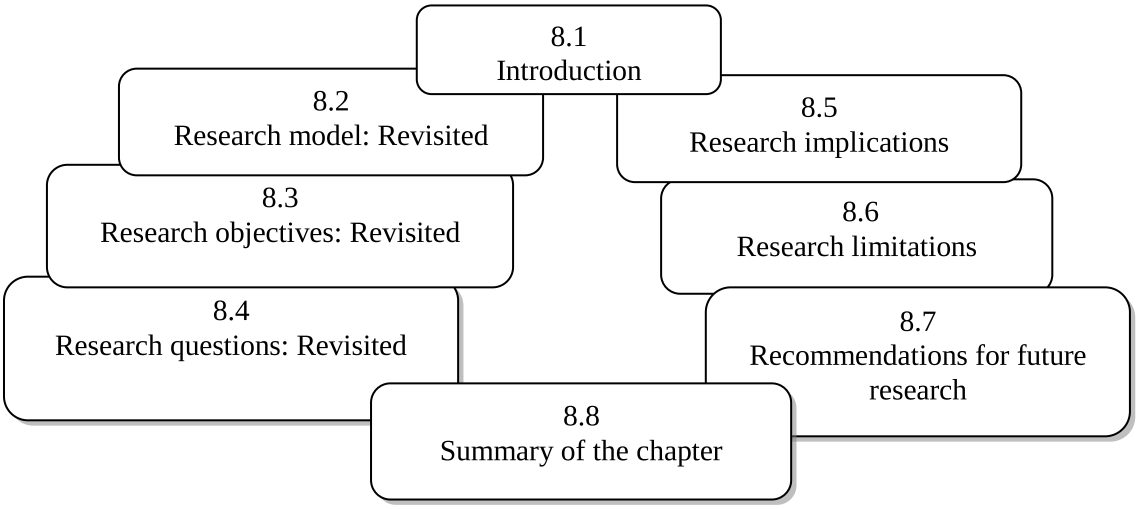


Figure 8-1: Structure of chapter eight

8.2 Research model: Revisited

This research adopts the extended resource-based view (ERBV) to investigate the research phenomenon. The ERBV perspective builds on the resource-based view (RBV) in that competitive advantage accrues from the resources that are valuable, rare, inimitable, and non-substitutable (Barney & Hesterly, 2006). However, ERBV takes a more integrated approach when considering the proliferation and significance of inter-firm alliances in competitive advantage (Dyer & Singh, 1998; Lavie, 2006; Mathews, 2003). From an ERBV perspective, competitive advantage can be generated through effective collaboration and relational resources (Wang & Wei, 2007). Relational antecedents include partner-specific investment, inter-firm interaction routines and long term relational orientation (Patnayakuni et al., 2006). These antecedents allow for the development of partner-specific behaviours which may be managed through information communications technology (Patnayakuni et al., 2006). Such behaviours reflect collaboration in shaping and sharing information, as well as integration of supply chain processes. These in turn are a reflection of supply chain visibility (SCV) (Wang & Wei, 2007). Taken together, it is contended that these factors will influence performance in a manner that can generate and sustain a competitive advantage.

This study aimed at developing and examining an integrated model for improving SCV. The model is driven mainly by the capabilities of asset visibility; specifically those associated with returnable transport asset management (RTAM) systems. Hence, a two-stage model was developed as illustrated in figures 8-2 and 8-3.

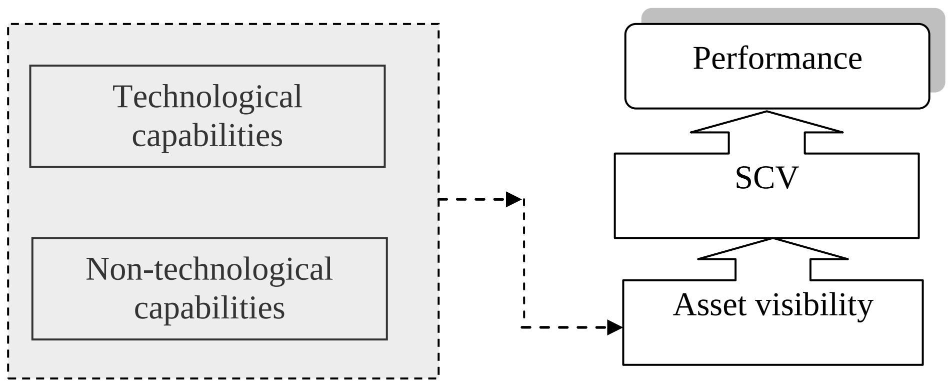


Figure 8-2: Initial conceptual model

The research endeavoured first to explore the main capabilities associated with asset visibility adopting an integrated perspective informed by theory and practice. As such, asset visibility capabilities were initially classified in terms of technological and non-technological capabilities (Barratt & Oke, 2007) which were later re-classified based on RBV/ERBV as core and complementary capabilities. The exploratory stage resulted in four key capabilities: core technological, core non-technological, complementary technological and complementary non-technological. For the purpose of further investigation, the influence of these four capabilities on SCV and firm performance were examined. The outcome of the first stage informed the primary stage of the research.

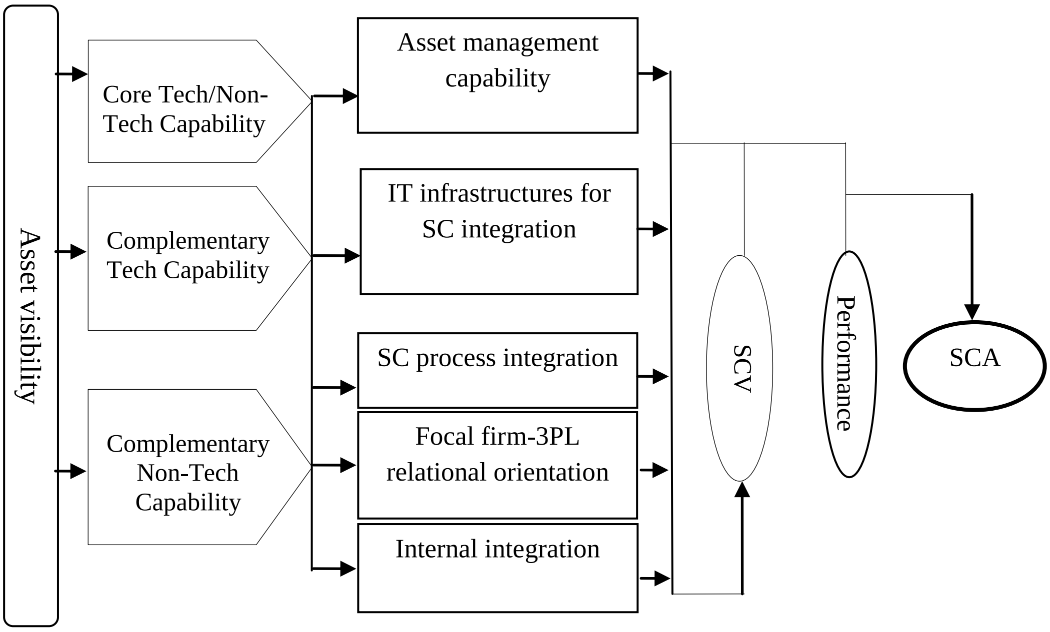


Figure 8-3: Research final model

In the focal stage, an integrated model of the impact of asset visibility capabilities on SCV, firm performance and sustainable competitive advantage (SCA) was developed and tested. The findings of the focal stage revealed three key capabilities after combining core technological and core non-technological ones forming asset management capability along with complementary technological and non-technological capabilities (see figure 8-3). Complementary technological capability is concerned with IT infrastructure for supply chain integration whilst complementary non-technological capability is formed by supply chain process integration, focal firm-3PL relational orientation and internal firm integration.

8.3 Research objectives: revisited

The research had two key consecutive objectives: (1) to explore the main capabilities of asset visibility; and (2) to examine the impact of these capabilities on SCV, firm performance and SCA.

To achieve these objectives the research adopted a critical realist approach using abductive logic. The key mechanism of critical realism is triangulation, so that a sequential exploratory strategy for data collection was implemented. A qualitative approach using an in-depth site-based case study supported by field-expert interviews constituting the pilot study was initially undertaken followed by a quantitative approach carried out through a survey.

Initially, the case study was conducted and data collected mainly through in-depth site-based semi-structured interviews. The case study facilitated a detailed investigation of the asset visibility capabilities that are driven by RFID and allowed the comparison of innovative data capture technology with traditional manual systems. Field-expert interviews were conducted to ensure the study was taking a holistic approach to the issues, to enrich the preliminary findings and to inform the initial conceptual model. From the pilot study came the key asset visibility capabilities and related hypotheses were then developed.

Secondly, the survey stage of this research focused on a quantitative investigation of asset visibility capabilities and their impact on SCV, firm performance and SCA. The survey's initial findings refined and reshaped the asset visibility capabilities. Finally, research hypotheses were tested and key findings and related implications were then presented.

8.4 Research questions: Revisited

The research adopted a focal firm perspective when answering the following main questions:

1) *What are the capabilities that constitute managing assets for visibility?*
2) *How can these capabilities be used to enhance supply chain visibility?*
3) *How do the capabilities required for visibility impact firm performance and in turn sustainable competitive advantage?*

As illustrated in figure 8-3, asset visibility capabilities are formed by three key types of capabilities: (1) Core capability associated with the asset management system; (2) complementary technological capability associated with IT infrastructure for supply chain integration; and (3) complementary non-technological capability in terms of supply chain process integration, focal firm-3PL relational orientation and internal firm integration.

The empirical findings provided support for the research model and related hypotheses. The positive impact of asset visibility capabilities on SCV was confirmed as well as on

SCA through the mediated effect of SCV and firm performance. This section draws briefly on the key findings concerned with each of the asset visibility capabilities arising from answering the research questions.

Asset management capability

The research concluded that asset management capability is influenced by core technological and core non-technological aspects. *Core technological capability* is mainly concerned with tracking and tracing capability driven by technology. This capability includes the ability to manage assets individually; locate the right assets; provide information about current physical condition in terms of quality; and save historical information about assets. This capability represents a good asset management system that requires innovative data capture technology such as RFID. *Non-technological aspects* are associated with process-related capability that is concerned mainly with transport logistics activities including shipping, transport and delivery (McFarlane & Sheffi, 2003). This capability includes the ability to reduce time, errors, waste and to enhance process information (Becker et al., 2009). Although asset management capability was expected to have a greater impact on SCV, the research findings revealed that in current supply chains this capability has the lowest magnitude among other capabilities of asset visibility. The research found that the majority of current RTAM systems are manual or use barcodes systems.

The research contributes to the theory by shedding light on the obsolescence of today's RTAM systems that directly undermine asset visibility and in turn SCV. In addition, the study empirically shows that these systems can be substantially improved through the introduction of innovative data capture technology, specifically RFID. It can be concluded that improved asset management systems are able to enhance asset visibility, SCV and in turn firm performance, which can create and sustain a competitive advantage.

IT infrastructure for SC integration

Complementary technological capability is represented through IT infrastructure for supply chain integration but it is only considered a capability if it involves information sharing activities. Data consistency along with cross-functional supply chain management application integration systems constitutes IT infrastructure for supply chain integration (Angeles, 2009; Rai et al., 2006). The research contributes to theory by confirming the findings of related operations and supply chain literature emphasising the significance of this capability in attaining SCV and firm performance (e.g. Angeles, 2009; Rai et al., 2006).

The research also demonstrated that IT infrastructure for supply chain integration as a complementary capability of asset visibility can significantly predict SCA through the mediated effect of SCV and firm performance. This finding contributes to theory by confirming that IT as a sole physical resource cannot be a source of SCA, only capability that is formed over a long period and shaped by internal and external interaction routines can generate a competitive position (Barney, 1991; Tyler, 2001; Vickery, Droge, Setia, & Sambamurthy, 2010). In addition, this study argues that IT capability has only an indirect effect on SCA.

Due to the obsolescence of current tracking and tracing systems, these systems are seen as the weakest link in current IT infrastructure for supply chain integration. This undermines supply chain integration, specifically at an operational level. As such, the study argues that today's supply chain integration is driven mainly by the progress of the orders associated with financial transactions not the actual flows of products. Hence, visibility as the key outcome of supply chain integration is constrained at an operational level. The research empirically found that the use of RFID as an example of inter-organisational systems should be integrated with supply chain IT infrastructure. This integration results in enhanced asset visibility and positively predicts SCV leading to better performance.

As depicted in figure 8-3, complementary non-technological capabilities of asset visibility are presented through three sub-capabilities: supply chain process integration, focal firm-3PL relational orientation and internal integration. Next, the research draws respectively on each of them.

Supply chain process integration

Supply chain process integration as a complementary capability of asset visibility is represented through physical, financial and information flow integration. The key mechanism of this integration is information sharing and its outcome is visibility. The research revealed that this capability is able to predict with a high degree of significance

SCV. Supply chain process integration capability is also able to influence SCA by considering the mediated effect of SCV and firm performance.

The research showed that the cruxes of this capability are inter-firm relationships that are developed over time through internal and external interaction routines. As such, co-ordination and integration between supply chain partners are established. The scope of this integration influences the scope of information sharing and in turn, the scope of SCV. The study suggested three levels of visibility including operational, tactical and strategic. The research argues that SCV should be reflected by the three levels.

Physical flow integration as an important determinant of supply chain process integration indicates the progress of shipping processes from the shipper's firm to the consignee's firm and the return of returnable transport assets to their supplier. The research contributes to theory by shedding light on physical flow integration as a constraint for enhancing current supply chain process integration mainly due to inefficient asset management practices, specifically those related to reverse flow of returnable transport assets. This leads to poor asset visibility at an operational level that causes serious problems e.g. late delivery, delivery errors and dissatisfied customers.

The research confirmed empirically that the adoption of innovative data capture technology (e.g. RFID) is able to facilitate both forward and backward physical flow integration through better asset management practices resulting in streamlined supply chain operations. This requires simultaneous adoption of the same standards of technology between supply chain trading partners and entails higher levels of co-operation (Dutta et al., 2007; Wamba et al., 2008). The issue of how to apportion the costs of this technology is still an implementation issue and can be co-operatively or opportunistically negotiated.

The study also concluded that enhancing physical flow integration reflects better financial flow integration as the second determinant of supply chain process integration. This financial determinant is concerned with the progress of the ordering process. Moreover, the research findings illustrated that enhanced integration at an operational level facilitates information flow integration on the tactical and strategic levels e.g. sharing demand forecasts and sales information.

The research deduced that in current supply chains, supply chain process integration is able to predict SCV and firm performance in a way that can create competencies through which SCA can be generated and sustained. The research argues that the magnitude of this effect could be increased if better asset management practices driven by innovative data capture technology are in place.

Focal firm-3PL relational orientation

The research concluded that focal firm-3PL relational orientation capability of asset visibility is able to predict SCV and firm performance in a way that can transform this capability into a competency; i.e. exceeding above average performance to create and maintain a competitive advantage.

The research findings indicated that in current supply chains, focal firm-3PL relational orientation capability has the greatest magnitude of impact on asset visibility compared to the other capabilities. As such, focal firm-3PL relationship capability is a key source of focal firm's visibility at an operational level

The research findings demonstrated that 3PL is an important partner that can co-operate with a focal firm by establishing relational interaction routines, relational asset specificity and long term relationships (Dyer & Singh, 1998; Patnayakuni et al., 2006). This facilitates certain levels of information sharing leading to better visibility at different levels, which informs decision-making process for better performance.

This finding confirmed the recent trend in related academic literature to address the key role the 3PL plays in managing contemporary supply chains (Hertz & Alfredsson, 2003; Jayaram & Tan, 2010; Lai et al., 2008). The research findings revealed that outsourcing is the predominant pattern of logistics service provider, whilst the most prevalent patterns of managing returnable transport assets are manual and barcodes systems (see appendices D and E). This limits asset visibility, especially when considering current features of transport logistics related to cross-docking systems, distribution centres and consolidation of products (Hesse & Rodrigue, 2004; Lemoine, 2004).

The results indicated that with the adoption of more advanced asset management systems (e.g. RFID), as an asset-specific investment by a 3PL, the increased collaboration and integration between the 3PL and the focal firm might enhance SCV, specifically at an operational level resulting in improved operational performance. In considering time reduction and real time activities as key competences in managing contemporary supply chains (Bhatnagar & Teo, 2009; Christopher, 2000; Stalk, 1988; Towill, 1996; Yusuf et al., 2004), above average operational performance influences these competencies in a way that might create and sustain competitive advantage.

Internal firm integration

Internal firm integration, as a complementary capability of asset visibility, is represented mainly through two key dimensions of cross-functional teams, formal and informal communication channels. The research findings confirmed that this capability has a positive impact on SCV. In addition, it can predict SCA through the mediated effect of SCV and firm performance.

The findings highlighted that in today's supply chains, internal firm integration was only able to interpret a small amount of the changes in asset visibility. This finding on the lack of internal visibility is in line with related results indicating the predominance of outsourcing. In addition, the lack of physical flow integration, due to poor asset management practices, constrains internal integration. The research contributes to theory by confirming the significant effect of internal integration on SCV and in turn, firm performance (Droge et al., 2004; Flynn et al., 2010; Gimenez & Ventura, 2005; Pagell, 2004). In addition, the findings revealed that in the current business environment, the internal integration capability is mature enough to influence firm performance in a way that might lead to SCA. The gap between the influence of internal integration on asset visibility and on SCV is quite stark. This gap reflects the lack of integration at an operational level. Although the significant role of logistics as a value-added activity is recognised in some current supply chains, there are still sectors where logistics is seen as a non-core and costly function (Mortensen & Lemoine, 2008). This perspective augments the problem of poor asset management practices.

The key dimension of today's' competitive differentiation between firms and among supply chains is real time activities and on-time delivery both of which are driven mainly by internal and external integration at an operational level, specifically physical flow integration. It is contended that internal firm integration has more of an influential effect on firm performance compared to external integration (Flynn et al., 2010; Gimenez & Ventura, 2005). The research empirically indicated that with the adoption of improved asset management systems better external and internal logistics arrangements are expected. This leads to enhanced operational-based visibility as the foundation of SCV leading to better performance.

Finally, the research findings indicated that in modern supply chains, firm size negatively predicts SCV. In other words, large sized firms that are engaged in more complex supply chain activities and relationships have less visibility compared to small and medium size firms. However, firm size did not show any impact on attaining SCA.

8.5 Theoretical perspective: Revisited

This section revisits the study's theoretical perspective. In addition, the study examines other alternative theoretical approaches that could have been used to investigate in this study.

E/RBV was used as the study's theoretical perspective and it has shown potential in attaining sustainable competitive advantage (SCA) through the indirect impact of asset visibility capabilities mediated by SCV and firm performance. Here the study turns to the extent to which E/RBV is the most appropriate theoretical lens in the context of contemporary RTAs track and trace systems by drawing on other theories that could have been utilised.

This section starts with the practical insights of the research findings followed by the theoretical ones, followed by an overview of the likely insights provided by several alternative theories.

Practical insight

This study was mainly driven by the use of innovative tracking technology at RTAs level that is, according to E/RBV, not a source of SCA, unless the associated technological, relational and managerial capabilities are considered. The limitations of the data collection, specifically those associated with the survey have altered the research focus on innovative practices towards a generic view considering various tracking systems; see sample characteristics limitations, p.357. Thus, the study was limited in its ability to prove the actual effect of asset visibility triggered by innovative tracking technology capability on SCV and in turn, SCA.

The findings have illustrated the prevalence of manual and barcode tracking systems that have a limited effect on SCV and can be an indication of their limited impact on SCA. Interestingly, asset management capability has shown potential in predicting

SCA. The relative contradiction between the effect of this capability on SCV and on SCA can be interpreted.

- *Firstly,* the direct effect of asset management capability driven by technology on SCA does not support the argument made by the extant literature (e.g. Jeffers, 2010; Mata et al., 1995; Ordanini & Rubera, 2008; Zahay & Handfield, 2004), so that the study's main interest is the indirect effect of this relationship. According to the research findings, the significant positive effect of asset management capability on SCA is influenced by the multiple mediation effect of SCV and performance that are affected by other complementary factors.
- *Secondly,* based on the multiple mediation findings this positive effect is the weakest effect among other factors proving minimal contribution towards SCA, see mediation findings of asset management capability, p. 288.
- *Thirdly,* process-related capability as a sub-construct of asset management capability could be influenced by other internal firms' managerial and organisational practices (e.g. the use of low-tech tracking systems; see chapter 4, P.109) along with technological ones that might contribute positively to this capability.

E/RBV deals with the capabilities that are developed over time and can create and sustain business value. The findings illustrated that the capabilities of innovative tracking systems are not well-developed yet. This is due to the relatively novel nature and the challenges facing the widespread diffusion of innovative tracking technology, specifically those related to cost and the difficulty to allocate this cost to SC partners, return on investment and common standards. Recently, progress has been made to overcome these barriers both in the academic literature and in practice (see chapter 4, p.109). However, it might still take some time to overcome these issues and to establish business cases on a large scale considering RTAs as the most feasible level across current supply chains. E/RBV can be an appropriate perspective once the capabilities associated with innovative tracking systems are established and become mature enough in a way that may create and sustain a business value.

The study's pilot findings along with literature indicate a higher maturity level of innovative tracking technology within closed-loop RTAs. This is due to more control over transport logistics operations and less technical and financial challenges related to sharing costs and returns, the use of common standards and sharing sensitive information with SC partners (cf. Hellstrom, 2009; Ilic et al., 2009b; Tajima, 2007).

Therefore, closed-loop RTAs that are managed using innovative tracking technology is a feasible candidate to enhance CSV and performance and to gain competitive advantage in the current business environment.

It can be concluded that the investigation of the actual impact of innovative asset management capability on SCA was constrained. Thus, in the context of contemporary RTAs' track and trace systems, SCA based on E/RBV might not be the most appropriate theory due to the immaturity of innovative tracking systems specifically in open-loop RTAs pattern, mainly the limitations of tracking technology capability as the key driver for enhanced asset visibility across a supply chain.

Theoretical insight

E/RBV has some theoretical limitations that had an influence on the research measurement process and findings.

First, E/RBV has been criticised as being tautological that might constraint the measurement process of SCA (Priem & Butler, 2001). To reiterate, the logic of E/RBV is based on the idea of VRIN (valuable, rare, inimitable and non-substitutable) resources and capabilities developed through internal and external path dependency, causal ambiguity and social complexity (see for example, Barney, 1995; Mathews, 2003). It is not possible to know and in turn to measure exactly these distinctive capabilities as this contradicts the assumptions of the theory. According to Peteraf (1993), " *in some cases causal ambiguity may make it impossible for a firm to evaluate its resources or even to identify them*". In addition, the idea of accruing superior rent or performance as the outcome of these distinctive capabilities is not easily quantifiable or measurable and in turn not comparable. Thus, the study had to rely on the above average performance compared to company's peers or industry average as a quantifiable indicator for competitive advantage.

ERBV and the relational view seeks SCA through resources spanning firms' boundaries that entail developing and sustaining relational capabilities driven by long-term relationships built on mutual trust and information sharing (Dyer & Singh, 1998). The logic behind ERBV is built on win-win relationships. This is not always the case in real life situations. For example, if a firm has a dominant power over its supply chain trading actors, it can force them to operate according to its operational rules known as arms-length relationship.

RTAs are a typical example of resources travelling across a supply chain and managed by different parties. The way of managing these assets influences the level and the mechanism of relational governance among SC partners specifically when considering innovative tracking systems. This in turn, requires different theoretical approaches and assumptions to manage different situations. Hence, other theoretical perspectives may still be considered along with E/RBV relying on win-win relationship such as transaction cost theory working through arms-length relationship.

As part of its criticism, E/RBV focuses on creating business values through a combination of a bundle of firm's unique resources and capabilities, but it is a limited platform from which to explain the mechanisms of attaining these values (Denrell, Fang, & Winter, 2003; Hoopes, Madsen, & Gordon, 2003). Hence, E/RBV does not provide sufficient explanation about the creation and the development of specific capabilities that might be critical when using a new process or adopting a new technology. With respect to the adoption of innovative tracking systems, alternative theoretical approaches are needed to fill this research gap. Here, absorptive capacity is suggested as an alternative theoretical approach. In addition, E/RBV overlooks market entry timing and its associated advantages that could add further insight when dealing with the adoption of innovative tracking systems; therefore the study draws on the first mover advantage literature.

The alternative theoretical approaches

In this section, the research suggests alternative theories that could be useful when investigating innovative tracking systems, a relatively new research phenomenon, aiming to address some of the weaknesses of the employed theoretical approach (E/RBV). These alternative perspectives incorporate absorptive capacity (AC), first-mover-advantage (FMA) and transaction cost economics (TCE). This section commences by introducing an overview of these theoretical perspectives along with the adopted E/RBV, see table (8-1). This will be followed by the details of each of these perspectives.

Table 8-1: Innovative tracking systems: alternative theoretical perspectives

	E/RBV	*AC*	*FMA*	*TCE*
Logic and objective	Firm's idiosyncratic capabilities that are valuable, rare, inimitable and non-substitutable can create and maintain competitive advantage	Firm's unique knowledge-based capabilities can create and sustain competitive advantage through the ability to assimilate and exploit new knowledge	Firm's first to use a new technology, conduct a new process, provide a new product is qualified to accrue long-term competitive advantage	Firms can avoid risk from opportunistic behaviour due to uncertainty through contractual safeguards. The level of asset specificity and uncertainty determines make or buy decision.
Time dimension	Capabilities are shaped over long period through social complex organisational routines, path dependency and causal ambiguity	Time is an influential factor in the development of AC capability in terms of knowledge aggregation shaped through path dependency	FMA is maintained as long as gained advantages are not copied by the followers that constitutes lead time between the first mover and the followers	The duration of the exchange relationship varies based on the length of the contract
Mechanism	Intra/inter-firm relationships based on mutual trust and information sharing	Acquisition, assimilations, transformation and exploitation	Entry barriers lengthen the lead-time between the first mover and the imitators	Well-crafted contract allows enforcement and monitoring
Scope	Individual firm or supply chain perspective	Individual firm or supply chain perspective	Individual firm or supply chain perspective	buyer-supplier or inter-firm contractual relationship
Relational governance mechanism	Win-win relationship through internal and external cooperative behaviour	Win-win relationship based on Internal and external cooperative behaviour	Win-win relationship through internal and external cooperative behaviour and	Arms-length relationship and opportunistic behaviour
Unit of analysis	Internal and/or external firm's core and complementary capabilities	Internal and/or external firm's absorptive capacity capability	Lead time between launching the investment and the response by late entrants	Transaction-based contract

	E/RBV	*AC*	*FMA*	*TCE*
Information nature	Tacit knowledge is more influential	Tacit knowledge is more significant	Tacit knowledge is more important	Explicit agreed information is the key
Limitations and criticism	Lack of empirical bases; E/RBV is self-verifying (tautological); Various resource configurations can yield a similar value for firms and therefore would not be CA; the product markets' role is less well articulated within RBV (Lieberman & Montgomery, 1998; Priem & Butler, 2001).	Due to its overlapping with other areas (such as strategic alliances, organisational learning, knowledge management and RBV), AC research may be subject to reification that may occur when the AC construct is separated from its original assumptions and relationships (Lane, Koka, & Pathak, 2006).	The economic arguments of FMAs based on entry barriers overlooked " product-market contingencies e.g. demand uncertainty that moderate these sources of FMAs", so that the firm might choose to be first mover or a late entrant (Kerin, Varadarajan, & Peterson, 1992).	TCE is "bad for practice" as its logic is far different from the market (Ghoshal & Moran, 1996); The relation between asset specificity and boundary choice (make-or-buy decision) has limited effect on opportunistic behaviour and failed markets (Poppo & Zenger, 1998); focusing on understanding the contract details is much more important than the boundary choice (Poppo & Zenger, 1998)
Examples of the key papers	(Wernerfelt, 1984), (Barney, 1991), (Zhu, 2004),(Wade & Hulland, 2004), (Lewis et al., 2010)	(Zahra & George, 2002), (Szulanski, 1996), (Cohen & Levinthal, 1990), (Lane & Lubatkin, 1998), (Lane et al., 2006)	(Lieberman & Montgomery, 1998), (Dos Santos & Peffers, 1995), (Cottrell & Sick, 2002), (Kerin et al., 1992)	(Williamson, 1979, 1998, 2008), (Ghoshal & Moran, 1996), (Robertson & Gatignon, 1998), (Poppo & Zenger, 1998, 2002),

Source: prepared by the researcher

Absorptive capacity (AC)

The definition and the dimensions of AC

Absorptive capacity perspective has been employed by different management research fields (strategic management, technology management, organisational economics, etc.) to analyse various organisational phenomenon (Zahra & George, 2002). Absorptive capacity is seen as a substantial construct to trigger internal innovation through the firm's ability to utilise external knowledge (Cohen & Levinthal, 1990).

Cohen and Levinthal, (1990) Provides the most widely used definition of absorptive capacity that indicates "*the firm's ability to recognise the value of new, external information, assimilate it, and apply it to commercial ends*". This definition has been revisited twice by Zahra and George, (2002) and then by Todorova and Durisin (2007) who verified the reliability of this definition. Zahra and George (2002) suggest four dimensions for absorptive capacity incorporating knowledge acquisition and assimilation constituting potential absorptive capacity and transformation and exploitation representing realised absorptive capacity. Both potential and realised absorptive capacity contribute to competitive advantage (Zahra & George, 2002). *Knowledge acquisition* indicates the organisation's ability to identify and acquire external knowledge that is critical to its operations. *Assimilating information* points to organisation's routines and processes that facilitate analysing, processing, interpreting and understanding external knowledge (Szulanski, 1996). *Transformation* refers to organisation's ability to combine prior knowledge and the new knowledge through developing and refining the routines that allow this to happen. *Exploitation* of transformed knowledge refers to the routines that help organisation to refine, extend and optimise already established capabilities and competences or to develop new ones. According to absorptive capacity, knowledge accumulated over time allows the assimilation and exploitation of novel knowledge (Zahra & George, 2002).

AC and E/RBV

AC and E/RBV share the same logic and can be seen as complementary perspectives. In his work focusing on knowledge-based theory for the firm, Grant (1996) discerns that RBV is concerned with the transferability of resources and capabilities of a firm as a significant factor of its ability to gain and maintain competitive advantage whereas, AC determines the knowledge's potential for accumulation through the ability to add knowledge to prior knowledge. This constitutes causal ambiguity of knowledge-based capability (Conner, 1991). Hence, AC allows better understanding of the diverse of firm's capabilities based on the ability to assimilate existing explicit and tacit knowledge. Thus, AC could be seen as a roadmap for understanding the development of the capabilities associated with the adoption of a new knowledge or technology.

The mechanism of AC

AC matches the logic underpinning E/RBV - the idea that firm's idiosyncratic resources determines its performance (Hervas-Oliver, Albors-Garrigos, & Baixauli, 2011). AC sheds the light on internal and external capabilities as the core of firm's ability to assimilate and exploit external knowledge (Cohen & Levinthal, 1990; Lane et al., 2006; Malhotra et al., 2005). Knowledge created, managed, and well-exploited over time by a firm constitutes a knowledge-based capability. A firm's bundle of knowledge-based capabilities shaped over long period through path dependency can be source of gaining and sustaining competitive advantage (Lane et al., 2006; Zahra & George, 2002). The absorptive capacity construct might occupy a moderator role between the adoption of new knowledge and the outcome of this new knowledge.

If the influence of the new knowledge is within the boundaries of a firm, so the focus of AC might be limited to the internal firm's capabilities. With respect to the supply chain management perspective, if the source of the new knowledge is SC partners, external firm's capabilities are considered as well (Malhotra et al., 2005).

AC as an alternative perspective within this study

E/RBV considers a bundle of organisation's distinctive resources and capabilities to create business values, yet it does not illustrate the mechanisms or the conditions through which firms can attain value by the deployment and the combination of resources (Denrell et al., 2003; Hoopes et al., 2003). In addition, E/RBV does not focus on individual capabilities. To reiterate, it does not show how individual capabilities are developed over time (Lieberman & Montgomery, 1998). Hence, E/RBV may not be a sufficient guide to know about the formation and the development of the specific capabilities needed especially when adopting a new technology such as novel tracking technology.

In considering innovative tracking technology, absorptive capacity may be limited to the internal firm's capabilities or extended to cover external firm's capabilities. With respect to the individual firm's view, some work has already been conducted highlighting the importance of absorptive capacity focusing on internal capabilities. Bendoly, Citurs, and Konsynski (2007) investigate the impact of internal infrastructure in terms of technical, operational and organisational capabilities on RFID perception and commitments. They concluded that the complementary effects of these capabilities significantly affect RFID perception and commitments. In her study, Angeles (2008) concluded that firms that can comply with RFID mandates have better absorptive capacity attributes than those who cannot.

These studies have revealed the importance of studying absorptive capacity as an influential factor for successful implementation of innovative tracking systems and calls for future research in this area. Future research may consider different industry sectors and various types of innovative tracking systems especially with the increasing trend towards integration and coupling of these systems, see chapter 4, p.109.

In relation to the supply chain perspective the absorptive capacity construct is less well articulated in extant literature. For example that firms acquire and assimilate new knowledge related to innovative tracking technology sourced by supply chain trading partners to enhance performance and to gain superior rent. Although internal firms' capabilities are still important, more attention needs to be devoted to inter-firm knowledge-based capability. In addition, intertwining the absorptive capacity construct along with other theories such as contingency theory might be beneficial for the sake of understanding the contextual conditions under which certain managerial practices are effective (Sousa & Voss, 2008).

First mover advantage (FMA)

The concept of FMA

The idea behind first mover advantage perspective is that companies which are the first to introduce a specific product or service to the market, use a new process and/or technology or approaching a new market may be eligible to gain a long-term competitive advantage (Kerin et al., 1992). The early adopter of innovative technology such as innovative tracking technology might be qualified to gain the advantages of being first movers. These advantages incorporate diminishing various costs, gaining a strong reputation as technology leaders, brand loyalty, enhancing market share, and reaching the mature stage in the learning curve associated with the technology (Cottrell & Sick, 2002; Dos Santos & Peffers, 1995). Although, FMA is seen as one of the firm's strategies to gain long-term competitive advantage (Powell & Dent-Micallef, 1997), FMA relying on technology itself might only guarantee temporary competitive advantage as the followers can easily imitate the technology (Clemons & Row, 1991).

FMA and E/RBV

It is argued that FMA and RBV are related theoretical approaches due to the relation between resource aggregation and the market entry timing that helps to overcome the lack of empirical base problem associated with RBV (Lieberman & Montgomery, 1998) In other words, the strengths and weaknesses of an organisation's resources and capabilities influence the optimal entry timing.

The mechanism of FMA

Entry barriers are the key mechanism of FMA. Entry barriers make the time longer for the followers to learn how to get the whole benefits of a new technology, so that early adopters may continue receiving the FMA benefit as they can keep ahead on the technology utilisation learning curve (Dos Santos & Peffers, 1995). Following the same strand, firms that can distinguish themselves and keep the lead in learning associated with innovative tracking systems might gain and maintain a competitive advantage (Tajima, 2007).

FMAs has been criticised for overlooking the product-market contingencies that moderate the sources of FMA and might cause a firm to intentionally decide to be first mover or late follower (Kerin et al., 1992). It is argued that early entrants or adopters may attain FMA, late entrants may also realise real values from delay (Cottrell & Sick, 2002). As a counter perspective to first mover advantage constituting a criticism to this perspective, late entrants or followers might gain real values when they wait until circumstances are optimal before deciding on launching a new initiative. The advantages that may be gained by the followers or late entrants incorporate the opportunity to know more about a new process or technology before making any strategic investment decision, avoiding sunk cost and loss due to investing in obsolete or non-promising technology, the chance to observe market and customers reaction to a new product or system (Cottrell & Sick, 2002).

The key influential factor through which a firm may decide to be a first mover or a follower is the significance of uncertainty level of the potentials or the risks associated with an investment (Cottrell & Sick, 2002).

FMA as an alternative perspective within this study

E/RBV, with its focus on firm's resources and capabilities, overlooks market entry timing that could add further insight when investigating innovative tracking practices across supply chains.

With respect to innovative tracking systems, extant literature has shown few studies have adopted the first mover advantage perspective when investigating the real value of these systems in supply chain management considering individual firm perspective (e.g. Ju, Ju, & Sun, 2008; Tajima, 2007). Tajima (2007) who adopted FMA along with organisational learning theory developed four propositions concerned with how RFID may create and maintain a competitive advantage. These propositions incorporate process automation may lead to SCA through enhancing SC efficiencies; closed-loop tracking may result in SCA by realising innovation, the use of RFID can improve supply chain visibility that may create a contemporary competitive advantage, supply chain visibility along with prior experience of closed-loop tracking may lead to SCA. As counter argument, another study has contended that there is no sign of first mover advantage related to RFID adoption because RFID is based on "open standards and is available to all firms" (Ju et al., 2008). According to this study, the only considered advantages are the increase in SC efficiency and in availability of customer goods. Both studies lack of empirical investigation. Further empirical investigation is in need to test the propositions developed by both studies.

Additional investigation is also needed considering different firm's organisational and technological factors. e.g. firm size, top management support, industry support, market trend, intra/inter organisational information systems and IT infrastructure (Tajima, 2007). On the other hand, second mover or late entrant advantages related to innovative tracking systems is less well articulated in current literature. With respect to FMA, extant literature has almost overlooked a supply chain as a unit of analysis. This study argues that closed-loop supply chains using innovative tracking technology at RTAs level is a good candidates for this level of analysis as they seem to be more mature than the open-loop ones.

Transaction cost economics (TCE) theory

The definition and the logic of TCE used here

Critically associated with the economist Williamson, transaction cost economics has developed over decades, indeed Williamson himself made changes to his own initial positions. Here the key aspects of TCE relevant to this study are examined not the entire body of TCE work.

Transactions are seen as the exchanges of goods or services between economic actors, these actors are technologically separate units, inside and/or outside the firm (Williamson, 1985). TCE, explains why specific functions are executed by firms and others by markets (Coase, 1937). A firm may decide to centrally, perform certain activities when the cost to organise transactions through the market are greater than the costs to coordinate the activities centrally. Between market and entirely vertically integrated firms there are various intermediate positions, that allows alternative coordination patterns for economic activities. Williamson (1975) argues that investigation into firms' transactions needs to be made to effectively understand firms.

Clemons and Row (1992, p.3) classified transaction costs into coordination costs (*"the direct costs of integrating decisions between economic activities such as search and bargaining costs"*), and transaction risk that is concerned with "*the exposure to being exploited in the relationship*". TCE supports two key assumptions of human behaviour including bounded rationality and opportunism through which the three key dimensions of transactions are shaped incorporating asset specificity, transaction uncertainty and frequency (Williamson, 1975). To mitigate their effects, each of these three dimensions requires effort and cost to structure an agreement between the trading parties (e.g. buyer and supplier) (Roehrich, 2009)

Transaction uncertainty has been classified in terms of primary and behavioural uncertainty (Williamson, 1985). Primary uncertainty is associated with the underlying transaction and influenced by natural events, technology, regulations and consumer preferences (Sutcliffe & Zaheer, 1998). This type of uncertainty may negatively affect the implementation of transactions through encountering coordination, communication and technological problems. On the other hand, behavioural uncertainty is concerned with the risk of opportunistic behaviour on transactions due to incomplete contracts.

TCE differentiates between various types of asset specificity incorporating human asset specificity, physical asset specificity and site specificity (Williamson, 1985). Asset specificity and transaction uncertainty result in an increase in coordination costs and transaction risk (Williamson, 1975). In considering transaction frequency, it is contended that transaction frequency diminishes the costs associated with uncertainty and asset specificity (Williamson, 1985).

TCE as an economic concept is concerned with "*how trading partners protect themselves from the hazard associated with exchange relationship"* (Shelanski & Klein, 1995, p.2). Hence, "*transaction cost economics adopts a contractual approach to the study of economic organisation*" (Williamson, 1996, p.54). Inter-firm exchange based on asset-specific investment might lead to risk due to the absence of some form of governance mechanism (i.e. the incompleteness of contracts) resulting in cost and performance losses (Williamson, 1979). Opportunism risk is quite high when one trading party has to invest in a specific asset for a specific exchange relationship (Williamson, 1975). The party who makes asset-specific investment is under high risk if the other party tries to restructure the exchange relationship to get better terms. The opportunism risk is maximised if the duration of the exchange relationship was expected to be long and if uncertainty about the continuation of this relationship is high (Cannon et al., 2008).

TCE and E/RBV

In considering a supply chain perspective, ERBV is driven by relational governance that is underpinned by the assumptions of mutual trust and long-term relationships. Building on these assumptions, E/RBV is a widely accepted approach to enhance performance and to gain SCA since 1990s (Hoyt & Huq, 2000). However, this approach is not always the case in managing supply chain relationships. The use of straightforward entity power might impose a different pattern of supply chain relationships to maximise the benefits of the powerful party. In addition, asset specificity and uncertainty might be other influential factors of the type of relational governance.

The mechanism of TCE

The key mechanism of TCE is how to contract to eliminate adversarial and opportunistic behaviour against a backdrop of the uncertainty of the business environment. Formal control within TCE is established through contract enforcement and monitoring as a primary safeguard. A "*complex contract defines remedies for foreseeable contingencies or specify processes for resolving unforeseeable outcomes*" (Poppo & Zenger, 2002, p.3). That is to say, contracts are a governance mechanism enforcing contractual obligations through providing pressure of legal enforcement or non-legal retribution in terms of economic and legal sanctions (Roehrich, 2009, p.40).

With respect to the level of asset-specificity, the trade-off between different mechanisms of formal control, uncertainty and the frequency of transaction is the most efficient way of managing transaction costs (Riordan & Williamson, 1985).

TCE as an alternative perspective within this study

The study of vertical inter-firm relationships is one of the most common applications of the TCE framework (c.f. Dyer, 1996; Dyer & Singh, 1998; Grover & Malhotra, 2003). As an alternative approach to ERBV, TCE provides a different theoretical perspective in managing inter-firm relationships that may add additional theoretical insight for innovative tracking practices across supply chains.

The extant literature has confirmed that the use of IT has participated in reducing the transactions costs in particular, coordination costs (c.f. Bakos, 1991; Cash & Konsynski, 1985). It is contended that information sharing facilitates collaboration that in turn can reduce transaction costs, mainly coordination costs, as firms can diminish SC uncertainty and therefore the cost of contracting (Yigitbasioglu, 2010). It is argued that innovative tracking technology such as RFID has the potential to improve transaction processes and in turn to lower transaction costs, yet there are still issues related to uncertainties, privacy, security, and cost (Zipkin, 2006). According to Cannon et al., (2008) TCE theory might provide a pessimistic view that firms are not likely making sufficient investment to implement and to integrate RFID into their SCs. The same authors state that TCE can be used to describe cases in which RFID should initially be implemented internally to stimulate process improvement.

With respect to innovative tracking systems, extant literature indicates that firms with large supply chains have the power to force the adoption of these systems across a supply chain. Accordingly, firms' decisions about the adoption of innovative tracking systems consider the needs of their most important customers (Barratt & Choi, 2007). Current literature has provided prominent examples illustrating the influence of the entity power (mainly the buyer dominates the supplier) on the exchange relationships in which innovative tracking technology is considered asset-specific investment. Mandated compliance was the key trigger for early adopters of RFID following "Slap-and-Ship" implementation (Tajima, 2007). In 2003, Wal-Mart and Tesco as two of the largest international retailers forced their top 100 suppliers to use RFID tags at RTAs level by the end of 2006 (Barratt & Choi, 2007; Wamba et al., 2008). In addition, the US

Department of Defence mandated the use of RFID tags by its suppliers. Here, weak or less powerful suppliers might be under the risks raised by TCE theory (Cannon et al., 2008). Although recent literature has indicated benefits gained by some Wal-Mart's suppliers, this is not always the case as some suppliers have to use the RFID tagging to RTAs just before shipping or they have to outsource this service to a 3PL just before the delivery to Wal-Mart (Holmström et al., 2009). More investigation may be needed to know how this risk could be minimised and how more benefits can be gained to the less powerful partner in the exchange relationship considering the trade-off between formal control, uncertainty and the frequency of transaction under TCE perspective.

With respect to logistics services, the increasing trend towards outsourcing of integrated logistics service has resulted in higher risk in managing this exchange relationship because of the great extent of separation of control and ownership, uncertainty due to asset specificity, competition in transport market (Dyer & Singh, 1998; Halldorsson & Skjoett-Larsen, 2006). In the mid 1980s the transaction agreement between the shipper and the 3PL tended to rely on more formality and mutual obligations through *arms-length relationship* under transaction cost economies to mitigate the effect of the opportunistic behaviour and to reduce transactional ambiguity (Zheng et al., 2008). Here, the powerful supplier of logistics service dominates the buyer in an exchange relationship. Figure (8-4), exhibits different levels of logistics service provider's relational governance influenced by the level of asset specificity that innovative tracking technology is an example of it. Although the way of managing this risk has changed since 1990s towards trust-based relationships (Hoyt & Huq, 2000), transactional-based relationship with high asset specificity is still one of the considered approaches in managing outsourcing (cf. Hofenk, Schipper, Semeijn, & Gelderman, 2011; Williamson, 2008). With respect to technological resources, contractual and relational governance are integrated approaches in managing outsourcing (cf. Hofenk et al., 2011; Poppo & Zenger, 1998; Silverman, 1999).

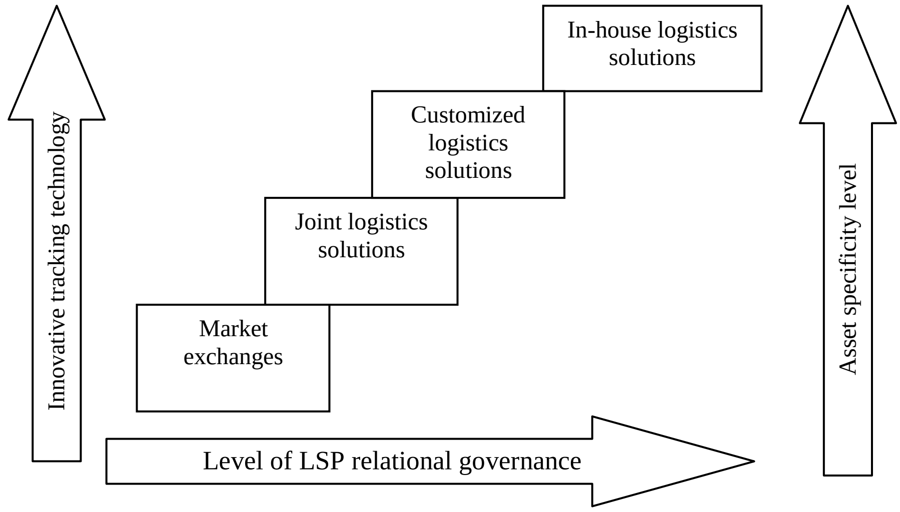


Figure 8-4: Levels of LSP's relational governance
Source: Adapted from Halldorsson and Skjøtt-Larsen (2004).

In the context of innovative tracking systems employed by the buyer (e.g. manufacturer, retailer) or the seller (e.g. 3PL, supplier) as asset-specific investment, more investigation is required related to dyad and inter-firm contracts design that considers sharing technology cost and return, process standardisation, data management and other technical and managerial implementation issues. In addition, how contractual relationships along with relational orientation based on trust and information sharing can work together to maximise the benefits of innovative tracking systems on supply chain visibility and in turn performance.

To conclude, with the proliferation of innovative tracking systems across supply chains, TCE can provide a useful theoretical insight in managing related exchange relationship.

8.6 Research implications

In this section, the research addresses the key managerial, theoretical, methodological and practical implications. The following section starts with the key managerial implications.

8.6.1 Managerial implications

This study is the first known academic initiative taking a comprehensive view of the capabilities constituting asset visibility. Most of the available literature in this area has paid great attention to innovative data capture technology itself as a main source of improving SCV (e.g. Asif & Mandviwalla, 2005; Attaran, 2007; Lee & Park, 2008). However, real-life applications of similar data capture technology have revealed different outcomes. Therefore, the capabilities through which the endowments of technology can be perceived seem to be less well articulated. This research contributes in filling the research gap through developing and investigating an integrated managerial model informed by theory and practice, and driven mainly by asset visibility capabilities for improving SCV and in turn, firm performance for competitive advantage.

The trend in most of the academic literature in this area is to focus on one aspect, however this study has adopted a multi-dimensional approach exploring four types of capabilities: core technological, core non-technological, complementary technological and complementary non-technological. The study examined each capability in relation to SCV and firm performance that result in SCA. The findings supported the research model and the associated hypotheses.

This study is a step forward towards a theoretical, methodological and practical understanding in the area of asset and SCV especially with the proliferation of innovative IT applications. The following sections highlight the key theoretical and practical implications of this research.

8.6.2 Theoretical implications

The extended resource-based view, as the main theoretical lens in this study, has proven to be appropriate to investigate asset visibility capabilities within conventional supply chains. The resource based view fits well within the in-house supply chain context. This study contributes to theory through providing asset visibility capabilities and their impact on SCA as support for the assumptions of ERBV and the relational view.

The research contends that the extended resource-based view is an appropriate perspective for investigating many supply chain issues. In addition, most of the available operations and supply chain literature do not pay enough attention to the influence of the pattern of the chain when tackling various topics. This research illustrated how supply chain type (e.g. in-house or outsourced) affected the investigation of the research problem. The research claims that supply chain type should be more explicitly considered when examining various supply chain topics.

8.6.3 Methodological implications

This research adopted a sequential exploratory strategy, so that a mixed-method approach was employed. The research provides support for methodology literature that suggests the use of this research design when investigating a new phenomenon (e.g. Creswell, 2009; Neuman, 2006). The use of photography as part of the site-based observation proved valuable twofold. Firstly, photographs aided the researcher in recalling key information during analysis. Secondly, the photos were also useful for other readers in understanding existing practices.

8.6.4 Practical implications

- This is one of the first academic studies, which empirically proved that current asset management systems that are manual-based or barcode-based are a constraint for improving visibility, performance and SCA.
- The research informs practitioners and business decision makers of the significance of asset visibility in enhancing their firms' performance and competitiveness.
- The research emphasises the pre-requisite capabilities for enhancing the expected outcome of adopting innovative asset management systems or enhancing current performance of established systems.
- Internal integration is an important capability triggering many supply chain improvement initiatives.
- As a final point, the cost of innovative data capture systems, specifically RFID is still a substantial concern for many businesses as well as assessing its return on investment (Lee & Ozer, 2007). This research provided an in-depth managerial interpretation of the impact of these systems on SCV and firm performance that could create and sustain competitiveness.

8.7 Research limitations

Zikmund (2000) suggests that one of the main purposes of exploratory research is to obtain a better understanding of the research topic and its limitations. Since this research implemented an exploratory sequential strategy, the main limitations of this research are as follows.

8.7.1 Philosophical and methodological limitations

This research adopted critical realism as a philosophical paradigm that ontologically sees reality as probabilistic and imperfect. Although internal validity of the research has been proved, external validity i.e. generalisability of the research findings is limited due to the nature of social science research which is oriented by practice.

8.7.2 Sample characteristics limitations

- The characteristics of the sample, specifically that concerned with the type of asset management systems, altered the research original orientation from a pure focus on only innovative systems towards a generic focus which included various types of these systems. This happened due to unavailability of an appropriate source e.g. a database listing firms who use only innovative systems.
- Because innovative asset management systems are still immature within current supply chains, the empirical study indicated that only 14% of the cases use such systems. As such, the dominance of manual and barcodes systems eliminated further investigation of the impact of innovative systems on the research model.

8.7.3 Finding limitations

- The research findings are limited to returnable transport assets i.e. the assets travelling across supply chains carrying products.
- The implications of the research findings are more applicable to product supply chains rather than service ones.
- The research findings were mainly influenced by traditional asset management systems as the predominant pattern in current supply chains.

8.7.4 Practical limitations

- The limitation of the research resources restricted the opportunity to expand the pilot study data to cover more than one case study to avoid any limitations; field-expert interviews were conducted to mitigate this concern.
- Since the nature of a PhD study is framed by a specific time span, further investigation of innovative asset management systems to overcome the research limitations, specifically sample characteristics was not feasible.

8.8 Recommendations for future research

The research sees asset visibility and SCV as a rich area for further research and may offer a number of new insights into current supply chain processes and constructs. A number of avenues for future research exist:

8.8.1 Exploring further realities

In this research, asset visibility capabilities explained 65% of the variance in the research model. This means that 35% of the variance remains unexplained. Therefore, these capabilities present only part of reality, while other realities are still unknown and require exploration. Given that this research is mainly driven by a supply chain context, the internal firm context may play a role in interpreting some of this unexplained variance. This might include investigating other functional (e.g. manufacturing, marketing and finance), technical or managerial areas.

8.8.2 Validating the research findings

- Philosophically, adopting different philosophical stances such as positivism or interpretivism and those that entail adopting different research methods such as simulation, experimental design, action research, or longitudinal study;
- Methodologically, using another research strategy within the same paradigm the research followed such as sequential explanatory strategy or simultaneous exploratory/explanatory strategy. This research provided sufficient understanding of the research phenomenon, so that the use of structural equation modeling as a quantitative analysis technique is suggested for the purpose of enhancing external validity (Healy & Perry, 2000).
- Practically, replicating this study targeting only firms adopting innovative data capture technology such as RFID could add value;
- Managerially, replicating this study considering clustering different types of supply chains could have valuable managerial implications.

8.8.3 Extending the research

- Theoretically, adopting different theoretical perspectives to investigate the research phenomenon such as contingent theory, economic theory and social capital theory;
- Methodologically, further testing of the research hypotheses through the introduction of moderator variables such as industry type and firm size to gauge their influence on the strength of the established mediation relationships known as moderation mediation effect;
- Managerially, expanding the research focus through studying the transformation process from traditional asset management systems to innovative systems, especially

absorptive capacity, process redesign and the role of IT service provider as a key partner in this process;

- Managerially, expanding the scope of this research based on investigating technological and non-technological capabilities influencing internal firm's visibility and in turn performance.
- Practically, extending the research perspective through adopting different view rather than a focal firm one e.g. 3PL or supplier.

8.8.4 Recommendations for relevant research

- Although logistics is a substantial pillar of the supply chain integration construct, it is not as well articulated as it could be in the operations and supply chain literature;
- Assessing the influence of current changes in the supply and logistics environment on supply chain operations, especially in-house provision which has been overlooked recently due to the predominance of outsourcing;
- There is overlap between some supply chain constructs and their measures such as visibility and integration which requires critical examination to refine both constructs.
- The visibility concept needs to be restructured within a supply chain context considering different organisational levels of visibility including operational, tactical and strategic, and their managerial implications;
- A multi-dimensional perspective, informed by the integrated construct of supply chain, needs to be maintained when tackling many of supply chain topics.

8.9 Summary of the chapter

This conclusion chapter revisited the research model, objectives and questions. It highlighted the main findings. In addition, implications for theory and practice were presented. In conclusion, the research suggested some ideas for future research.

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Appendices

A. Semi-structured interviews questions for the case study

1. Would you please tell me about the title of your job and your main responsibilities?
2. How do you describe the size of your firm within telecommunication sector in UK?
3. What are the key business activities of your firm?
4. What are the main products or services provided by your firm?
5. How do you describe the characteristics of your key products (e.g. in terms of value, robustness, durability or sensitivity to temperature or humidity)?
6. Which types of returnable transport assets (e.g. trolleys, boxes, racks, and roll cages) do you use in your logistics network?
7. Who is responsible for managing your RTAs i.e. tracking, sorting, collecting, cleaning, maintaining?
8. What system do you use for RTAM (manual, Bar-coding (one/two dimensions) or RFID system (passive/active)?
9. Could you please explain how your tracking system works?
10. What were the main drivers for the adoption of the tracking system in your company?
11. What were the major problems with your previous RTAM system?
12. How do you describe your IT infrastructure in terms of supply chain applications and ICT and to what extent does RFID-RTAM system integrate within this infrastructure?
13. How can you evaluate the integration level of your firm's IT infrastructure and its business processes?
14. To what extent do you think that RTAM system using RFID has any influence on improving the way you manage your assets?
15. Do you think the use of this advanced data capture technology has helped you to have better visibility over your supply chain operations? If yes please explain.
16. How does this visibility influence your firm's performance?
17. How would you describe your relationship with your key supplier/s related to information sharing activities, mutual trust, goal congruence, etc.?
18. To what extent do you think your RFID-RTAM system has helped you to improve your relationship with your supply chain partners?

19. How do you assess your firm's internal integration in terms of cross-functional and internal communications channels?
20. To what extent do you think your firm's internal integration affects the performance of your asset management system?

B. The questions for field-expert interviews

1. Would you please tell me about your experience in the field of supply chain applications specifically, data capture technologies?
2. How do you technically explain the role of advanced data capture applications specifically RFID in improving asset visibility across supply chain?
3. RTAM practices are directly associated with transport logistics activities, how do you assess the impact of innovative asset management systems on the logistics performance?
4. Do you think industry type, product characteristics and/or firms' size have an influence on asset management practices?
5. What do you think the key drivers to implement innovative asset management systems are?
6. What do you think are the key factors influencing successful implementation of innovative asset management systems?
7. On your view, what are the key technological considerations to have a good RTAM system that is able to work with other supply chain applications?
8. How do you explain the required integration arrangements to better manage RTAs across a supply chain considering different partners i.e. manufacturer, distributor and customers?
9. How do you see the current role of 3PL in enhancing asset visibility practices and how might this influence the performance of other supply chain partners?
10. To what extent do you think a firm's internal integration practices, such as cross-functional teams, top management support, and proper communication channels, are influential elements for better asset visibility and in turn supply chain visibility?

C. The survey invitation email

Dear CIPS member,

Thank you for reading this email. In collaboration with CIPS, the University of Bath is conducting research aimed at improving supply chain visibility. We greatly appreciate how busy you are, so we have designed a questionnaire which takes approximately 10 minutes to complete.

To receive a summary report of the research, please add your email address to the end of the questionnaire. In addition, we will be running a joint workshop for survey participants to share key findings.

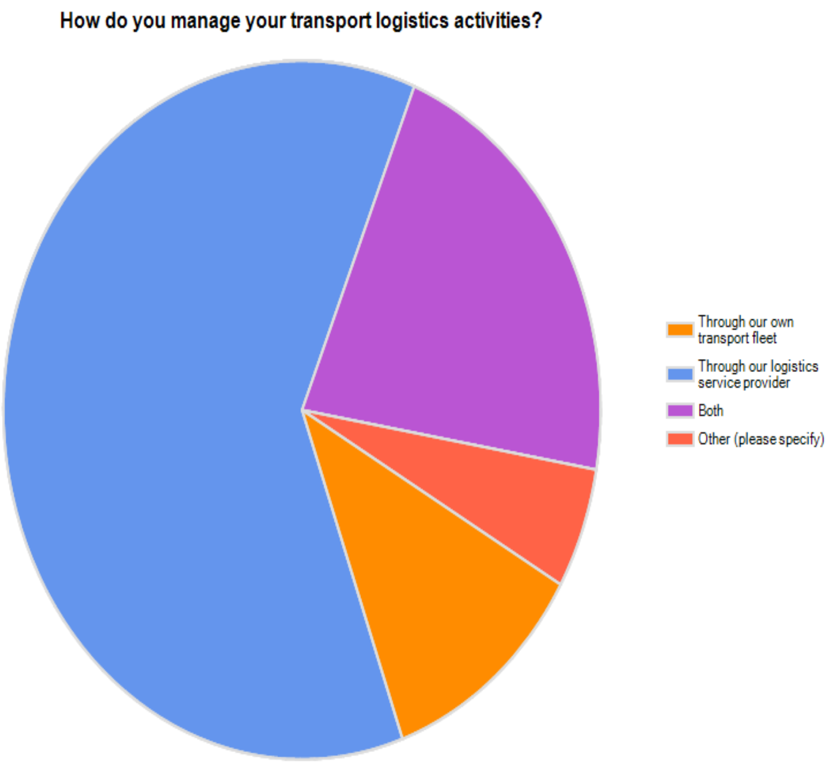
Be assured that all information will be treated with the strictest confidentiality. To begin the survey, please click on the link below:

http://www.surveymonkey.com/s/HKM8WBC

We greatly appreciate your time and help in conducting this survey.

Kind regards,
Gerard Chick,
Head of Knowledge and Research, CIPS
Michael Lewis,
Professor in Operations and Supply Management, University of Bath

D. The types and the magnitude of logistics service provider

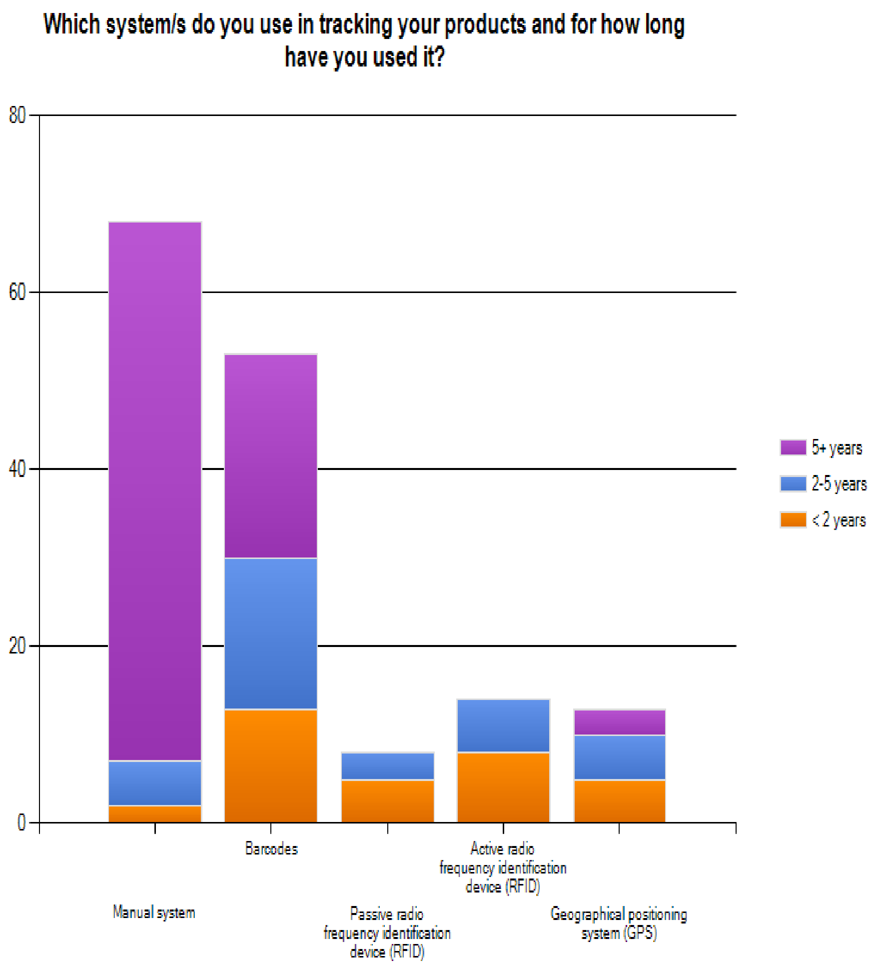


E. RTAM system considering the adoption period

Table (A) draws on the type of RTAM system among respondents' firms. Manual tracking system is still the most prevalent type among participants' firms and together with barcodes system constituted 69.4% of the sample. Both types of RFID along with GPS through which RTA tracking system is managed represented 23.8% among sample's firms.

Table A: RTAM system

Tracking system	<2 Yrs	2-5 Yrs	5+ Yrs	Total	%
Manual system	2	4	57	63	39.4
Barcodes	12	18	18	48	30
Passive RFID	4	4	-	8	5
Active RFID	7	8	-	15	9.4
GPS	6	5	4	15	9.4
Others		11		11	6.8

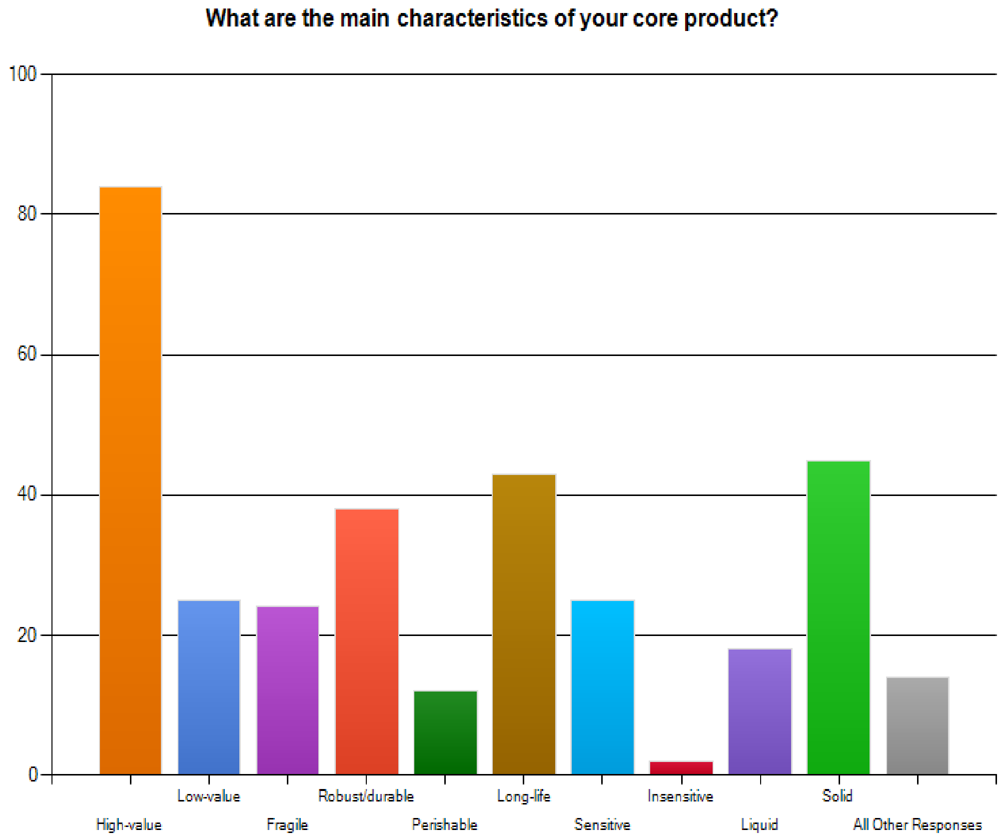


F. *Product characteristics*

Table (B) depicts product characteristics of the firms participating in the study. Among the sample, most of the products are high-value, durable, long-life, sensitive, and solid. Products are transferred across supply chains carried in RTAs. The predominant type of returnable transport assets are boxes (32.6%). Cases represent 20.1%, followed by cages (14.6%), trolleys (6.3%), trays (5.6%) and finally kegs (2%). The other types used represent 18.8% (e.g. drums and pallets).

Table B: Product characteristics

Product characteristics	Frequency	Frequency	Product characteristics
High-value	67	21	Low value
Robust/durable	33	21	Fragile
Long-life	36	7	Perishable
Sensitive	22	2	Insensitive
Solid	42	16	Liquid



G. *Firm's annual sales*

Table (C) presents the firm's annual sales that are classified in five categories. Most of the firms' annual sales are £250M or less representing 42.2% of the research sample while 31% of the sample their annual sales are greater than £250M.

Table C: Firm's annual sales

Firm's annual sales	Frequency	%
£1 - £50M	24	23.6
Over £50 – £250M	19	18.6
Over £250 - £500M	9	8.6
Over £500 - £1000M	5	4.9
Over £1000M	17	16.8
Missing	28	27.5
Total	102	100

H. Findings and discussion of the rudimentary analysis

This section depicts the results of the descriptive data analysis. To evaluate the study's employed constructs incorporating asset visibility capabilities, supply chain visibility, performance and sustainable competitive advantage, a seven-point Likert scale was employed ("1= strongly disagree" and "7= strongly agree"). Asset visibility capabilities are represented through five constructs constituting the independent variables including asset management, focal firm-3PL relational orientation, IT infrastructure for SC integration, SC process integration and internal firm capabilities. The following tables present the key descriptive data of each construct including the range, minimum, maximum, mean, standard deviation and the mode. The study reflects briefly on these results. However, it is important to note that this reflection is largely subjective. Descriptive data are not used to statistically test the relationships amongst variables. This section draws first on the constructs of independent variables that is followed by those related to dependent variables.

First: independent variable' constructs

1. Asset management capability

Results, as presented in table 1, illustrate that respondents are relatively disagree with half of the items constituting asset management capability (their mean scores were between 3.4 and 3.9). Four of these eight items are affiliated to tracking technology capabilities as sub-construct that incorporate "*the ability of a firm's tracking system to track RTAs on individual base and locate specific RTAs across a supply chain; identify current physical status of RTAs and maintain historical information of RTAs used in a supply chain.* The other four items are associated with process-related capability as the second sub-construct that include *"the ability of a firm's tracking system to reduce the return time of RTAs; reduce the return error of empty RTAs; reduce inefficient consumptions of firm's resources and provide updated information e.g. expected delays*".

In contrast, the respondents neither agree nor disagree on the second half of the items constituting asset management capability, which are mainly concerned with process-related capability. The answers on these items showed more inclination towards relative disagreement (their mean scores are between 4.0 and 4.4). These items incorporate "*the ability of a firm's tracking system to reduce delivery time to customers; maintain continuous flow of products across a supply chain; reduce delivery errors to customers;*

maintain quality of your products across SC operations; reduce waste associated with time and money; improve security aspects; minimise errors in data capture and provide accurate information e.g. check out/in activities".

Reflection on the study findings

These descriptive results, specifically those related to asset tracking capabilities that showed relative disagreement among respondents, might validate the research findings related to the prevalence of manual and barcode tracking systems that have limited technological capabilities compared to those associated with innovative tracking systems that are still immature.

The relative disagreement among respondents on half of the items forming asset management capability along with a relative inclination of the respondents to disagree on the second half of the items might reflect the study findings of the hypothetical relationships specifically, the non-significant effect of asset management capability on supply chain visibility within the multiple regression analysis.

Table (1) Asset management capability

	Range	Min	*Max*	Mean	S.D.	Mode
Your tracking system for your core product helps you to..						
..track RTAs on individual base across your SC	6.00	1.00	*7.00*	3.6354	2.01635	1.00
..locate specific RTAs across your SC	6.00	1.00	*7.00*	3.5521	2.06153	1.00
..identify current physical status of your RTAs	6.00	1.00	*7.00*	3.4688	1.90817	1.00
..maintain historical information of RTAs used in your SC	6.00	1.00	*7.00*	3.7789	1.93610	5.00
..reduce delivery time to your customer	6.00	1.00	*7.00*	4.0937	1.71113	4.00
..reduce return time of empty RTAs	6.00	1.00	*7.00*	3.5729	1.69050	4.00
..maintain continuous flow of products across your SC	6.00	1.00	*7.00*	4.3854	1.66935	4.00
..reduce delivery errors to your customers	6.00	1.00	*7.00*	4.3438	1.79372	4.00
..reduce return errors of empty RTAs	6.00	1.00	*7.00*	3.7604	1.88481	4.00
..maintain quality of your products across SC operations	6.00	1.00	*7.00*	4.3895	1.89790	6.00
..reduce waste associated with time and money	6.00	1.00	*7.00*	4.4632	1.84973	4.00
.. improve security aspects e.g. loss, counterfeiting and theft	6.00	1.00	*7.00*	4.1563	2.01222	4.00
..reduce inefficient consumption of your resources	6.00	1.00	*7.00*	3.9684	1.84767	4.00
..minimise errors in data capture	6.00	1.00	*7.00*	4.0316	1.81865	6.00
..provide accurate information e.g. check out/in activities	6.00	1.00	*7.00*	4.2211	1.79940	4.00
..provide updated information e.g. expected delays	6.00	1.00	*7.00*	3.7263	1.83606	4.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

2. Focal firm-3PL relational orientation capability

As presented in table 2, the focal firm-3PL relational orientation construct is measured using fifteen items. Two items illustrated relative agreement among respondents (their means are between 5.2 and 5.5) that combine "*you and your logistics service provider have a long-term relationship and do not take any intentional actions that can hurt your relationship*".

Ten items revealed that the respondents are neither agree nor disagree on ten items (their mean scores are over 4 and below 5). Nine items of these ten items were closer to relative agreement among respondents (their means are between 4.5 and 4.8). These nine items incorporate "*your logistics service provider has customised tools and machinery to your needs, has dedicated significant investment and capacity to your relationship, is involved in developing your logistics processes, is involved in quality and improvement initiatives, and you have created formal and informal arrangements for information exchange, and you have planned to anticipate and resolve operative problems, and you have developed ways to improve cost efficiencies, and you share best practices, and you have jointly established goals".* Only one item was closer to relative disagreement among respondents (its mean score is 4.3). This item is *"your key logistics service provider has knowledge about you that is difficult to replace".*

In contrast, the last three items that showed relative disagreement among respondents (their mean scores are between 3.7 and 3.9) are as follows "*your logistics service provider helps you to learn about new technologies and markets; and you manage your relationship based on trust; and you have a dedicated team for your continuous replenishment program (CRP) or other efficient consumer response (ECR) practices"*.

Reflection on the study findings

Most of the respondents are closer to relative agreement on the attributes constituting focal firm-3PL relationship (11 items out of 15). This might support the related research findings that 3PL is the predominant pattern of logistics service provider and reflect its important role in managing current supply chains.

Table (2): Focal firm-3PL relational orientation capability

	Range	Min	Max	Mean	S.D.	Mode
Your key logistics service provider..						
.. has customised tools and machinery to your needs	6.00	1.00	7.00	4.8333	1.6781	4.00
..has dedicated significant investment to your relationship	6.00	1.00	7.00	4.6456	1.6489	5.00
..has knowledge about you that is difficult to replace	6.00	1.00	7.00	4.3418	1.7822	4.00
..is involved in developing your logistics processes	6.00	1.00	7.00	4.5190	1.7011	4.00
..is involved in quality and improvement initiatives	6.00	1.00	7.00	4.5000	1.7037	4.00
..helps you to learn about new technologies and markets	6.00	1.00	7.00	3.9103	1.7520	4.00
..and you manage your relationship based on trust	6.00	1.00	7.00	3.9620	1.4801	4.00
..and you have created formal and informal arrangements for information exchange	3.00	3.00	6.00	4.6456	1.0746	5.00
..and you have planned to anticipate and resolve operative problems	3.00	3.00	6.00	4.5844	1.0680	5.00
..and you have developed ways to improve cost efficiencies	4.00	3.00	7.00	4.5000	1.1593	3.00
..and you have a dedicated team for your continuous replenishment program …	6.00	1.00	7.00	3.7179	1.6268	4.00
..and you share best practices	3.00	3.00	6.00	4.5000	1.0660	4.00
..and you have a long-term relationship	3.00	4.00	7.00	5.5443	1.0101	5.00
..and you have jointly established goals	6.00	1.00	7.00	4.7436	1.4983	5.00
..and you do not take any intentional actions that can hurt your relationship	5.00	2.00	7.00	5.2405	1.3887	6.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

3. IT infrastructure for supply chain integration

As illustrated in table 3, IT infrastructure for supply chain integration construct has been measured using eight items. The answers on these items showed that most respondents selected a middle position (their means are below 5 and above 4) i.e. they neither agree nor disagree. The respondents showed more inclination towards relative agreement (as their means are between 4.6 and 4.7) on two items incorporating; "*in your supply chain planning and transaction applications are able to be communicated in real time*".

In contrast, the respondents' answers on the other six items are closer to relative disagreement (their means are between 4.2 and 4.4). These six items are as follows: "*a firm's IT infrastructure supports the use of automatic data capture systems across your SC, allows common definitions of key data elements across your SC, offers consistency in storing the same data in different databases across your SC, in your supply chain customer relationship applications are able to be communicated with internal applications of your firm, and your SC applications are able to be communicated with internal applications of your firm*".

Reflection on the study findings

Most of the respondents showed more inclination towards relative disagreement that their firms' IT infrastructure supports the use of automatic tracking systems across their SCs. This result came in line with the descriptive findings of the first construct and might justify the non-significant effect of asset management capability on SCV. In addition, the inclination towards more relative agreement on that transaction applications are able to be communicated in real time might support the idea that current SCV is mainly driven by financial integration rather than physical integration.

Table (3) IT infrastructure for supply chain integration

	Range	Min	Max	Mean	S.D.	Mode
Your IT infrastructure…..						
..supports the use of automatic data capture systems across your SC	6.00	1.00	7.00	4.2874	1.87956	5.00
..allows common definitions of key data elements across your SC	6.00	1.00	7.00	4.4828	1.82274	4.00
..offers consistency in storing the same data in different databases across your SC	6.00	1.00	7.00	4.3333	1.85940	4.00
In your supply chain,…						
..planning applications are able to be communicated in real time	6.00	1.00	7.00	4.6180	1.67539	4.00
..transaction applications are able to be communicated in real time	6.00	1.00	7.00	4.7614	1.58291	5.00
..customer relationship applications are able to be communicated with internal applications of your firm	6.00	1.00	7.00	4.4382	1.63036	5.00
Your supply chain applications…						
..are able to be communicated with internal applications of your firm	3.00	3.00	6.00	4.4886	1.01703	4.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

4. Supply chain process integration

As illustrated in table (4), the supply chain process integration construct is measured using thirteen items. The answers on these items varied between relatively agree to neither agree nor disagree.

Three items indicated relative agreement among respondents (their means are between 5.0 and 5.6). These items include "*across your SC accounts receivable processes are automatically triggered when you ship to your customers; customers give you feedback on quality and delivery performance and inventory data are visible at all stages*".

The answers on six items were closer to relative agreements (their means are between 4.5 and 4.9). These items are as follows: "*across your SC accounts payable processes are automatically triggered when you receive supplies from your suppliers; inventory holding is minimised; production and delivery schedules are shared; performance metrics are shared; supply chain members collaborate in arriving at demand forecasts; and demand levels are visible*".

The last four items showed more inclination towards relative disagreement (their means are between 4.0 and 4.3). These items incorporate "*across your supply chain supply, chain-wide inventory is jointly managed with your suppliers and your logistics partners; suppliers and logistics partners deliver products and material just in time; distribution networks are configured to minimise total supply chain-wide inventory costs; downstream partners share their actual sales data with you*".

Reflection on the study findings

The answers on the supply chain process integration construct depicted that there is a relative agreement among respondents on the items constituting financial flow integration as a sub-construct of SC process integration (the first two items in table 4). This came in line with the study finding that current SCV is driven mainly by the progress of the orders rather than the actual flows of products. This conclusion is supported also by other descriptive results of this construct that exhibited respondents' inclination towards relative disagreement on most of the items forming physical flow integration as a sub-construct of SC process integration (three items out of four). These items incorporate "*across your supply chain supply, chain-wide inventory is jointly managed with your suppliers and your logistics partners; suppliers and logistics partners deliver products and material just in time; distribution networks are configured to minimise total supply chain-wide inventory costs*".

Table (4) Supply chain process integration

	Range	Min	Max	Mean	S.D.	Mode
Across your supply chain,…						
..accounts receivable processes are automatically triggered when you ship to your customers	6.00	1.00	7.00	5.0488	1.77710	6.00
..accounts payable processes are automatically triggered when you receive supplies from your suppliers	6.00	1.00	7.00	4.9878	1.82908	6.00
..inventory holding is minimised	6.00	1.00	7.00	4.6220	1.65283	6.00
..supply chain-wide inventory is jointly managed with your suppliers and your logistics partners	6.00	1.00	7.00	4.0617	1.74174	5.00
..suppliers and logistics partners deliver products and material just in time	6.00	1.00	7.00	4.1235	1.64608	6.00
..distribution networks are configured to minimise total supply chain-wide inventory costs	6.00	1.00	7.00	4.3333	1.58114	4.00
..production and delivery schedules are shared	6.00	1.00	7.00	4.7073	1.64420	6.00
..performance metrics are shared	6.00	1.00	7.00	4.9383	1.60737	6.00
..supply chain members collaborate in arriving at demand forecasts	6.00	1.00	7.00	4.5595	1.61582	5.00
..downstream partners share their actual sales data with you	6.00	1.00	7.00	4.0476	1.72791	3.00
..customers give you feedback on quality and delivery performance	3.00	4.00	7.00	5.6310	1.00336	6.00
..demand levels are visible	5.00	2.00	7.00	4.9524	1.52018	6.00
..inventory data are visible at all stages	5.00	2.00	7.00	5.1310	1.42084	6.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

5. Internal firm integration

As depicted in table 5, internal firm integration construct is gauged using eight items. The answers on half of these items indicated relative agreement among respondents (their means are between 5.1 and 5.8). These items are as follows: "*within your firm cross functional teams to solve problems are used; internal management communicates frequently about goals and priorities; openness and teamwork are not encouraged; and when problems or opportunities arise, informal, face-to-face meetings never occur"*. The results of the second half of the construct's items referred to neither agree nor disagree with more inclination towards relative agreement among respondent (their mean are between 4.5 and 4.9). These items include "*within your firm all departments are connected by a single central information system; communications from one department to another are expected to be routed through "proper channels"; when* *problems occur, finding someone to blame is more important than finding a solution; and formal meetings are routinely scheduled among various departments".*

Reflection on the study findings

The overall relative agreement among respondents on the attributes of internal firm integration capability might be an indication of the study findings that showed high correlation between internal integration and SCV as the latter construct has similar answers' pattern (this will be illustrated in the following section).

Table (5) Internal firm integration

	Range	Min	Max	Mean	S.D.	Mode
Within your firm,…						
..all departments are connected by a single central information system	6.00	1.00	7.00	4.7738	2.10765	7.00
..cross functional teams to solve problems are used	3.00	4.00	7.00	5.5357	.97494	5.00
..communications from one department to another are expected to be routed through "proper channels"	5.00	2.00	7.00	4.9524	1.42190	6.00
..internal management communicates frequently about goals and priorities	5.00	2.00	7.00	5.1071	1.37987	6.00
..openness and teamwork are not encouraged	6.00	1.00	7.00	5.4286	1.78539	7.00
..when problems occur, finding someone to blame is more important than finding a solution	6.00	1.00	7.00	4.9643	2.00269	7.00
..formal meetings are routinely scheduled among various departments	6.00	1.00	7.00	4.9024	1.41080	6.00
..when problems or opportunities arise, informal, face- -to-face meetings never occur	5.00	2.00	7.00	5.8929	1.18238	7.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

Second: Dependent variables

1. Supply chain visibility

As presented in table 6, supply chain visibility construct (acted as dependent as well as mediator variable within this study) was assessed through fourteen items representing two sub-constructs: information sharing and information quality. The answers on two items indicated relative agreement among respondents (their means range between 5.01 and 5.03). These two items include "*your supply chain trading partners and you exchange information that helps establishment of business planning; information* *exchange between you and your SC trading partners are interpretable*". On the other hand, the respondents' answers on the rest of the construct's items indicate neither agreement nor disagreement with more inclination towards relative agreement (their means are between 4.7 and 4.9); see table 6.

Reflection on the study findings

As previously mentioned, asset visibility at operational level is still a constraint for SCV mainly due to limited asset management capability. The inclination towards relative agreement among respondents on SCV construct might be limited at this level. It is expected that better asset visibility can lead to enhanced SCV.

Table (6) Supply chain visibility

	Range	Min	Max	Mean	S.D.	Mode
Your supply chain trading partners…						
..are informed in advance about changing needs	6.00	1.00	7.00	4.9012	1.41955	6.00
..share proprietary information with you	6.00	1.00	7.00	4.8025	1.42671	5.00
..keep you fully informed about issues affecting your business	6.00	1.00	7.00	4.7531	1.49609	6.00
..share business knowledge of core business processes with you	6.00	1.00	7.00	4.7284	1.43189	4.00
..and you exchange information that helps establishment of business planning	6.00	1.00	7.00	5.0370	1.35503	5.00
..and you inform each other about changes that may affect the other partners	6.00	1.00	7.00	4.8148	1.42400	6.00
Information exchange between your supply chain trading partners and you is..						
..timely	5.00	2.00	7.00	4.7407	1.35810	6.00
..up to date	5.00	2.00	7.00	4.8642	1.29183	6.00
..generated frequently	6.00	1.00	7.00	4.9012	1.27088	5.00
..accurate	6.00	1.00	7.00	4.8519	1.35195	6.00
..valuable and applicable to specific tasks	6.00	1.00	7.00	4.9259	1.35810	6.00
..consistently presented	5.00	2.00	7.00	4.7778	1.37840	5.00
..easy to understand	6.00	1.00	7.00	4.9259	1.42107	6.00
..interpretable	6.00	1.00	7.00	5.0123	1.35549	6.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

2. Firm performance

As exhibited in table 7, firm performance construct as mediator variable was evaluated using seven items. One of these seven items indicates relative agreement among respondents (its mean is 5.1). This item is "*you are able to keep a strong and continuous bond with your customers*". The answers on the other six items referred to neither agreement nor disagreement among respondents, with more inclination towards relative agreement (their means are between 4.5 and 4.8) apart from one item that was closer to relative disagreement (its mean is 4.3). The five items that referred more to relative agreement consist of "*you are able to offer timeliness of your after sales service; improve your productivity level; have precise knowledge of your customer buying patterns; increase sales of your existing products; find new revenue streams e.g. new products, new market*". Finally, the item that is closer to relative disagreement is "*you are able to shorten your product delivery cycle time".*

Reflection on the study findings

Interestingly, the only item that showed somewhat disagreement among respondents is mainly related to the performance of logistics activities that are directly related to the actual flows of products across supply chains. This might be a further indication for the limited effect of asset management capability as well as the constrained impact of physical flow integration.

Table (7) Firm performance

	Range	Min	Max	Mean	S.D.	Mode
You are able to…						
..shorten your product delivery cycle time	6.00	1.00	7.00	4.3704	.52023	5.00
..offer timeliness of your after sales service	6.00	1.00	7.00	4.7625	1.31442	5.00
..improve your productivity level	6.00	1.00	7.00	4.8519	1.21564	5.00
..keep a strong and continuous bond with your customers	6.00	1.00	7.00	5.1375	1.33828	6.00
..have precise knowledge of your customer buying patterns	7.00	.00	7.00	4.5556	1.58114	5.00
..increase sales of your existing products	3.00	3.00	6.00	4.5802	1.05906	5.00
..find new revenue streams e.g. new products, new market	6.00	1.00	7.00	4.7284	1.35104	

Note: Min: minimum, Max: maximum, S.D.: standard deviation

3. Sustainable competitive advantage

As seen in table 8, sustainable competitive advantage construct is represented through two sub-constructs including competitive advantage and sustainability of competitive advantage. Competitive advantage is measured using 14 items, whereas sustainability of competitive advantage is assessed through six items.

With respect to the first sub-construct, four items of the first sub-construct indicate agreement among respondents (their means range between 6.0 and 6.3). These items incorporate "*you are able to compete based on quality, offer products that are highly reliable, offer products that are very durable, offer high quality products to your customers*". Within the same sub-construct, other five items referred to somewhat agreement among respondents (their means are between 5.0 and 5.6). These items include "*you are able to offer competitive prices, deliver customer order on time, provide dependable delivery, alter your product offerings to meet client needs, respond well to customer demand for "new" features"*. The respondents' answers on the last five items indicated neither agreement nor disagreement. Three of these items illustrated more inclination towards relative agreement (their means range between 4.5 and 4.9). These items combine you are able to "*deliver product to market quickly, be first in the market in introducing new products, and lower time-to-market than industry average*." In contrast, two items were closer to relative disagreement (their means are between 4.2 and 4.4). These items incorporate "*you are able to offer prices as low as or lower than your competitors and to have fast product development".*

In relation to the second sub-construct, which is sustainability of competitive advantage, all the items revealed middle position i.e. neither agree nor disagree among respondents. All the answers were closer to relative agreement on these items (their means range between 4.7 and 4.8); see table 8.

Reflection on the study findings

The respondents' answers on the items constituting SCA construct demonstrated higher means compared to other constructs. This could be a reflection of a variety of the factors affecting SCA e.g. price, quality, flexibility, delivery time and innovation. The results revealed that in the current business environment, quality plays an influential role in attaining SCA compared to price, flexibility, delivery time and innovation.

Table (8) Sustainable competitive advantage

	Range	Min	Max	Mean	S.D.	Mode
You are able to..						
..offer competitive prices	5.00	2.00	7.00	5.0494	1.29326	6.00
..offer prices as low as or lower than your competitors	6.00	1.00	7.00	4.4198	1.61914	5.00
..compete based on quality	2.00	5.00	7.00	6.1975	.73177	6.00
..offer products that are highly reliable	2.00	5.00	7.00	6.3333	.70711	7.00
..offer products that are very durable	4.00	3.00	7.00	6.0123	1.16720	7.00
..offer high quality products to your customers	2.00	5.00	7.00	6.3875	.72030	7.00
..deliver customer orders on time	3.00	4.00	7.00	5.5309	1.02575	6.00
..provide dependable delivery	3.00	4.00	7.00	5.5875	.97687	6.00
..alter your product offerings to meet client needs	3.00	4.00	7.00	5.6790	1.04675	6.00
..respond well to customer demand for “new” features	3.00	4.00	7.00	5.6049	.97055	6.00
..deliver product to market quickly	6.00	1.00	7.00	4.8642	1.55526	6.00
..be first in the market in introducing new products	6.00	1.00	7.00	4.9630	1.52843	6.00
..lower time-to-market than industry average	3.00	3.00	6.00	4.5062	1.02620	4.00
..have fast product development	6.00	1.00	7.00	4.2346	1.59900	4.00
Compared to your major competitors, your…..						
..return on total assets in 2007 were..	6.00	1.00	7.00	4.7297	1.31688	4.00
..return on total assets in 2008 were..	6.00	1.00	7.00	4.8514	1.20140	4.00
..return on total assets in 2009 were..	6.00	1.00	7.00	4.8649	1.17420	4.00
..return on sales in 2007 were..	5.00	2.00	7.00	4.7838	1.12591	4.00
..return on sales in 2008 were..	5.00	2.00	7.00	4.8378	1.03404	4.00
..return on sales in 2009 were..	5.00	2.00	7.00	4.8082	1.06272	5.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

I. Construct overlapping issue

This part examines the overlapping issue among items constituting constructs of some independent variables and the dependent variable, mainly supply chain visibility (SCV) that might cause large value of R^2.

The potential overlapped constructs and their related items are as follows.

- Asset management capability as an independent variable includes three possible overlapped items which are: *tracking system helps to minimise errors in data capture, provide accurate information e.g. check out/in activities,* and *provide updated information (e.g. expected delays, route change).*

SCV as a dependent variable, specifically level of information quality sub-construct has three items that may be problematic which are: *information exchange between you and your supply chain trading partners is timely,* and *up to date and accurate*.

- Supply chain process integration as an independent variable includes three sub-constructs; financial, physical and information flows integration. It is suggested that the items constituting information flow integration might overlap with items representing level of information sharing as a sub-construct of SCV. The items related to information flow integration are as follows: *across your supply chain production and delivery schedules are shared, performance metrics are shared, supply chain members collaborate in arriving at demand forecasts, demand levels are visible,* and *inventory data are visible at all stages*. (N.B. another relevant item was deleted based on factor analysis result as it had no loading; this item is *downstream partners share their actual sales data with you*), see table 6-2, p.259.

  SCV as a dependent variable, specifically level of information sharing sub-construct incorporates the following items: *your supply chain trading partners are informed in advance about changing needs; share proprietary information with you; keep you fully informed about issues affecting your business; share business knowledge of core business processes with you; you exchange information that helps establishment of business planning;* and *you inform each other about changes that may affect the other partners.*

- IT infrastructure for SC integration as an independent variable incorporates cross functional SCM application system integration sub-construct which combines four items; two of them might overlap with the items pertaining to level of information quality. The two items are*: in your supply chain, planning applications are able to be communicated in real time* and *transaction applications are able to be communicated in real time.* The level of information quality as a sub-construct of SCV has two items seen to be problematic with the previous two items including: *information exchange between you* and *your supply chain trading partners is timely* and *up to date.*

Actions that have been taken

The following procedures has been performed to investigate the overlapping concern;

1- *The descriptive data for the items under investigation have been presented to assess the extent to which these data reflect similar patterns through comparing their means;*

2- *Bivariate correlation analysis has been conducted to check the extent to which each pair under investigation are correlated (N.B. although high R value is desired, the extremely large value i.e. >.8 may be indication for overlapping);*

Bivariate correlation (*R*) between independent and dependent variables is desired when testing their relationships. Collinearity, which is a relationship between two variables, or multicollinearity, which is a relationship between more than two variables, is a problem specifically considering the relationships between independent variables specifically within the multiple regression model (Hair et al., 1998). Here, the researcher uses the collinearity concept to check the suggested overlapping among items consisting independent variables and items representing the dependent variable. Extremely large correlation values i.e. *R* greater than 0.8 or 0.9 may indicate multicollinearity (Tabachnick & Fidell, 2007). The study implements this rule to check the suggested overlapping concern among certain variables.

3- *The scatter plots and R^2 linear are presented to show the degree to which each pair of items under investigation is powerful in predicting each other;*

4- *Data are checked for Chronbach's alpha if item deleted. In considering alpha value if an item is deleted, when any of these values is higher than the Chronbach coefficient alpha value, the associated variable should be deleted from the scale (Pallant, 2007, p.98). Therefore, if the value of Chronbach's alpha goes up upon the deletion of an item under investigation, this indicates that this item is not part of the examined construct and vice versa. The construct under investigation is supply chain visibility that is suggested to overlap with some other constructs;*

5- *If the outcome of step 4 shows that the item is part of the construct (i.e. if the value of Chronbach's alpha if item deleted < the value of Chronbach's alpha), the multiple regression model will be retested based on deleting this item/s from the model to check its impact on R^2 value;*

6- *The new R^2 value will reflect the degree of overlapping among items constituting both independent and dependent variables. Then the implications of this problem will be discussed and the recommendations for future research to avoid or eliminate its effect will be made.*

The following sections examine respectively, each of the proposed overlapped constructs according to the aforementioned testing procedures.

The overlapped constructs and their related items

First: Asset management capability and SCV

Asset management capability as an independent variable includes three suggested overlapping items incorporating *tracking system helps to minimise errors in data capture, provide accurate information e.g. check out/in activities,* and *provide updated information (e.g. expected delays, route change).*

SCV as a dependent variable, specifically the level of information quality sub-construct has three items seen to be problematic which are: *information exchange between you* and *your supply chain trading partners is timely, up to date and accurate*.

To examine the overlapping concern between the two construct, the study follows the aforementioned procedures.

1. ***The descriptive data for the investigated items of asset management capability and SCV***

Table (1) Suggested overlapped items within asset management capability construct

	Range	Min	*Max*	Mean	S.D.	Mode
Your tracking system for your core product helps you to..						
..minimise errors in data capture	6.00	1.00	*7.00*	4.0316	1.81865	6.00
..provide accurate information e.g. check out/in activities	6.00	1.00	*7.00*	4.2211	1.79940	4.00
..provide updated information e.g. expected delays	6.00	1.00	*7.00*	3.7263	1.83606	4.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

Table (2) Suggested overlapped supply chain visibility items

	Range	Min	Max	Mean	S.D.	Mode
Information exchange between your supply chain trading partners and you is..						
..timely	5.00	2.00	7.00	4.7407	1.35810	6.00
..up to date	5.00	2.00	7.00	4.8642	1.29183	6.00
..accurate	6.00	1.00	7.00	4.8519	1.35195	6.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

As depicted in table 1 and 2, the results indicate noticeable variation between the means of the independent variable items (asset management capability) and the items constituting SCV.

First, the mean of the item related to minimising errors in data capture that is affiliated with asset management capability is 4.03. In addition, the mean of the second item (your tracking system…. provides accurate information) within asset management capability is 4.22. On the other hand, the mean of the suggested overlapped item (information exchange… is accurate) within SCV as the dependent variable is 4.85, see table 2. This result illustrates more inclination towards relative agreement among respondents. Hence, relying on the descriptive results, overlapping among these variables is not observed.

Second, the mean of the third item (your tracking system…... provides updated information e.g. expected delay) within asset management construct is 3.72, (See table 1). This value refers to relative disagreement among respondents (the mean is over 3 and below 4). On the other hand, the means of the two suggested overlapped items (information exchange ….. is timely and up to date) within SCV construct are 4.74 and 4.86, see table 2. These values mean that respondents are more inclined towards relative agreement (the means are above 4.5 and below 5). That is to say, according to descriptive findings, the idea of overlapping between these items is not confirmed. Yet, further examination is performed in the following section relying on bivariate correlation.

2. ***Findings of the bivariate correlation analysis between the suggested overlapped items within asset management capability as independent variable and supply chain visibility as dependent variable.***

Table (3) Bivariate correlation among suggested overlapped items

Information exchange between your supply chain trading partners and you is..	..timely	..up to date	..accurate
Your tracking system…. ..minimise errors in data capture	.225	.220	.288*
..provide accurate information e.g. check out/in activities	.273*	.199	.265*
..provide updated information e.g. expected delays	.216	.182	.280*

(**) Correlation is significant at the 0.01 level, (*) Correlation is significant at the 0.05 level

As exhibited in table 3, collinearity problem does not exist (as all R values are < 0.8) between the items constituting asset management capability as the independent variable and the items forming supply chain visibility as the dependent variable. The largest significant *R* value is 0.288. Furthermore, some of these items are not significantly correlated. This came in line with the study findings that illuminated significant medium correlation (*R* = 0.31) between asset management capability and supply chain visibility, see table 6-5, p. 276. Therefore, according to the correlation findings no concern need to be raised about overlapping issue among investigated items. Further investigation is conducted in the following section using scatter plots and linear regression.

3. ***The scatter plots and R^2 linear to show the degree to which each pair of items under investigation (asset management capability items and SCV items) is powerful in predicting each other;***

   a. Your tracking system, minimise error in data capture (asset management capability construct) and information exchange is accurate (SCV construct)

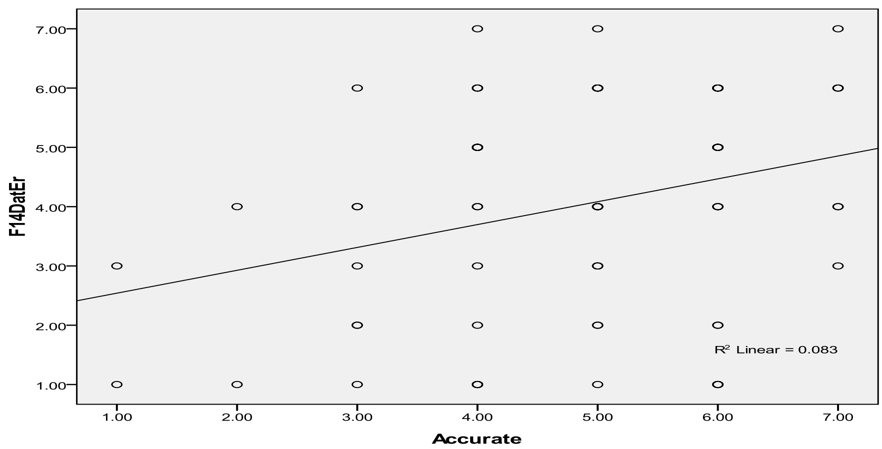


Figure 1: scatter diagram of the two investigated items (minimising errors & accuracy)

As seen in figure 1, the ability to minimise errors item that is related to asset management capability as an independent variable is a weak predictor for accuracy of information exchange as part of SCV as a dependent variable. The former item could explain only 8% of the variance in the latter item. This outcome matches the study findings related to the limited effect of asset management capability in predicting SCV. This provides further proof that overlapping is not a concern between these two items.

b. Your tracking system, provide accurate information (asset management capability construct) and information exchange is accurate (SCV construct)

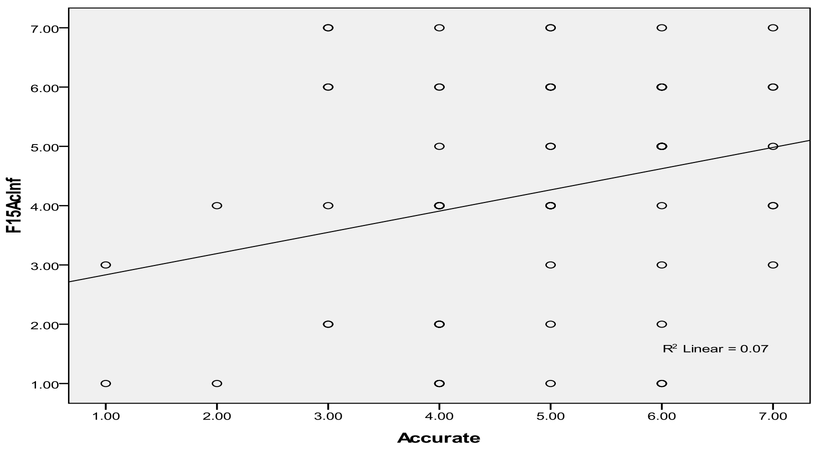


Figure 2: scatter diagram of the two investigated items (accurate info. & accuracy)

Figure 2 depicts the relationship between the ability of a firm's tracking system to provide accurate information (as an item of asset management capability construct) and the accuracy of the information exchange between a firm and its trading partners across a supply chain (as an item within SCV construct). The first item (independent variable) could only explain 7% of the variance in the second item (dependent variable) that indicates a weak explanation power. This came in line with the research findings associated with the weak relationship between asset management capability and SCV. Relying on this result, overlapping between the two items is not observed.

c. Your tracking system, provide updated information (asset management capability construct) and information exchange is up to date (SCV construct)

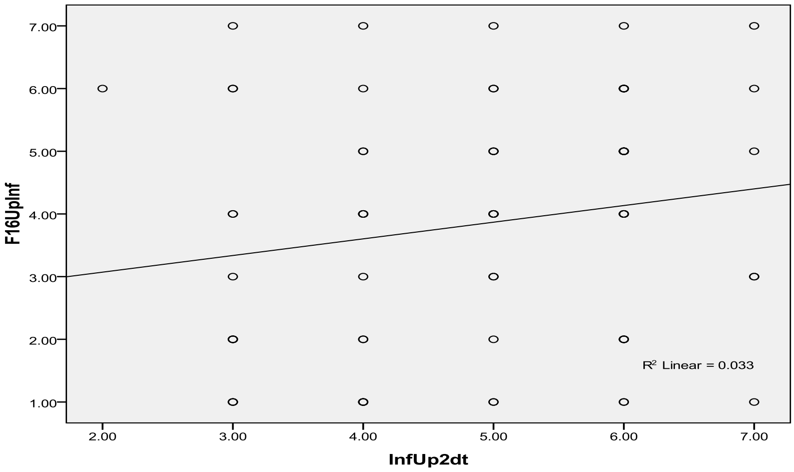


Figure 3: scatter diagram of the two investigated items (accurate info. & accuracy)

Figure 3 illustrates the relationship between the ability of a firm's tracking system to provide updated information (as an item of asset management capability construct) and the up to date information exchange across a supply chain (as an item within SCV construct). The former item represents the independent variable could predict only 3% of the variance in the latter item which is the dependent variable. to reiterate, the first item is a weak predictor of the second one. This result came in line with related research findings of asset management capability on SCV. Hence, according to this finding, overlapping between the two items is not detected.

4. ***To check the value of Chronbach's alpha if item deleted***

The construct under investigation is supply chain visibility as the dependent variable that incorporates some items suggested to overlap with other items within asset management capability construct. This section provides the results of the Chronbach's alpha values after adding the suggested three overlapped items incorporating *the ability of a firm's tracking system to minimise errors in data capture, provide accurate information, and provide updated information*. The study is more interested in the value of Chronbach's alpha when these items are deleted from the construct.

a. The ability to minimise errors

Table 4: Reliability Statistics

Cronbach's Alpha	N of Items
.958	15

Table 5: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Your tracking system for your core product helps you to.. **..** minimise errors in data capture	67.8000	272.973	.280	.968

As exhibited in table 4, Cronbach's alpha value is .958. The inclusion of the investigated item affiliated with asset management construct (the independent variable) which is associated with the tracking system ability to minimise errors in data capture within supply chain visibility construct as a dependent variable resulted in higher value of Cronbach's alpha if this item deleted (.968). In other words, removing this item from the construct enhances the reliability of the construct. This finding is a further proof that no concern should be raised about the overlapping between this item and SCV construct. Therefore, no further investigation is required.

b. The ability to provide accurate information

Table 6: Reliability Statistics

Cronbach's Alpha	N of Items
.959	15

Table 7: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Your tracking system for your core product helps you to.. **..** provide accurate information	67.8000	272.973	.334	.968

Table 6 indicates the value of Chronbach's alpha (.959) for supply chain visibility construct. Table 7 shows the increase in this value (.968) upon the deletion of the item related to the ability of a firm's tracking system to provide accurate information. This item is part of asset management capability construct as an independent variable. This outcome reveals that this item diminishes the reliability of SCV construct. This result confirms no overlapping between this item and SCV construct. Consequently, no further investigation is required.

c. The ability to provide updated information

Table 8: Reliability Statistics

Cronbach's Alpha	N of Items
.958	15

Table 9: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Your tracking system for your core product helps you to.. **..** provide updated information	67.8000	272.973	.269	.968

Table 8 demonstrates that the value of Chronbach's alpha when a new item is added to supply chain visibility construct becomes .958. Although this value confirms high reliability of this construct as it is greater than .7, table 9 illuminates that the deletion of the added item which is concerned with a firm's tracking system ability to provide updated information resulted in higher value of Chronbach's alpha (.968). This result proves that this item is not affiliated with SCV construct and in turn does not support the idea of overlapping between them. Hence, no further investigation is required.

To conclude, the concern raised about the possibility of overlapping between some items of SCV construct and some items related to asset management capability construct has been examined using various statistical techniques. The findings of these analyses have not confirmed the proposed overlapping between the two constructs. Consequently, no further investigation is required.

Second: SC process integration and SCV constructs

Supply chain process integration as an independent variable includes three sub-constructs; financial, physical and information flows integration. It is suggested that the items constituting information flow integration might overlap with items representing level of information sharing as a sub-construct of SCV. The items related to information flow integration are as follows: *across your supply chain production and delivery schedules are shared, performance metrics are shared, supply chain members collaborate in arriving at demand forecasts, demand levels are visible, inventory data are visible at all stages*. (N.B. another relevant item was deleted based on factor analysis result as it had no loading; this item is *downstream partners share their actual sales data with you*), see table 6-2, p.259.

SCV as a dependent variable, specifically level of information sharing sub-construct incorporates the following items: *your supply chain trading partners are informed in advance about changing needs; share proprietary information with you; keep you fully informed about issues affecting your business; share business knowledge of core business processes with you; and you exchange information that helps establishment of business planning; and you inform each other about changes that may affect the other partners.*

To examine the overlapping concern between the two construct, the study follows the aforementioned procedures.

1. The descriptive data for the investigated items of SC process integration and SCV

Table (10) suggested overlapped items within SC process integration construct

	Range	Min	Max	Mean	S.D.	Mode
Across your supply chain..						
..production and delivery schedules are shared	6.00	1.00	7.00	4.7073	1.64420	6.00
..performance metrics are shared	6.00	1.00	7.00	4.9383	1.60737	6.00
..supply chain members collaborate in arriving at demand forecasts	6.00	1.00	7.00	4.5595	1.61582	5.00
..demand levels are visible	5.00	2.00	7.00	4.9524	1.52018	6.00
..inventory data are visible at all stages	5.00	2.00	7.00	5.1310	1.42084	6.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

Table (11) suggested overlapped items within SCV construct

	Range	Min	Max	Mean	S.D.	Mode
Your supply chain trading partners…						
..are informed in advance about changing needs	6.00	1.00	7.00	4.9012	1.41955	6.00
..share proprietary information with you	6.00	1.00	7.00	4.8025	1.42671	5.00
..keep you fully informed about issues affecting your business	6.00	1.00	7.00	4.7531	1.49609	6.00
..share business knowledge of core business processes with you	6.00	1.00	7.00	4.7284	1.43189	4.00
..and you exchange information that helps establishment of business planning	6.00	1.00	7.00	5.0370	1.35503	5.00
..and you inform each other about changes that may affect the other partners	6.00	1.00	7.00	4.8148	1.42400	6.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

Drawing on table 10, most of the presented items that are related to SC process integration construct show more inclination towards relative agreement among respondents as their means range between 4.55 and 4.93. Only one item indicates relative agreement as its mean is more the n five (5.13). With respect to table 11, the means of six items affiliated with SCV construct range between 4.72 and 4.90 demonstrating that most of the respondents are closer to somewhat agreement on these items. One item has higher mean (5.03) referring to relative agreement among respondents.

The pattern of descriptive data of the indicated items with the two constructs reveals enough similarity to merit further investigation to check the overlapping concern among these constructs.

2. ***The findings of the bivariate correlation analysis between the suggested overlapped items within SC process integration construct as independent variable and supply chain visibility as dependent variable.***

Table (12) Bivariate correlation among suggested overlapped items

Your supply chain trading partners…	…are informed in advance about changing needs	..share proprietary information with you	..keep you fully informed about issues affecting your business	..share business knowledge of core business processes with you	..and you exchange information that helps establishment of business planning	..and you inform each other about changes that may affect the other partners
Across your supply chain.. ..production and delivery schedules are shared	.538**	.557**	.592**	.493**	.457**	.570**
..performance metrics are shared	.476**	.419**	.430**	.371**	.375**	.556**
..SC members collaborate in arriving at demand forecasts	.475**	.416**	.409**	.359**	.294**	.420**
..demand levels are visible	.582**	.475**	.556**	.444**	.406**	.551**
..inventory data are visible at all stages	.412**	.263*	.366**	.200	.218	.287**

(**) Correlation is significant at the 0.01 level
(*) Correlation is significant at the 0.05 level

Table 12 demonstrates that the highest correlation value (R) is .582 that is significant at the 0.01. This value is much lower than 0.8 suggesting that collinearity concerns do not exist between the SC process integration construct, representing an independent variable, and the SCV construct, as a dependent variable. The correlation values among investigated items are even relatively lower than the research finding that demonstrated larger correlation value between the two constructs (.71). SC process integration as an independent variable has the largest correlation value amongst other independent variables, see table 6-5, p.276. Therefore, according to bivariate correlation findings, the concern of overlapping between suggested items has not been confirmed. However, further investigation is conducted in the following section.

3. ***The scatter plots and R^2 linear to show the degree to which each pair of items under investigation (SC process integration items and SCV items) is powerful in predicting each other;***

<u>First item: Across your supply chain, production and delivery schedules are shared (SC process integration construct)</u>

a. Across your supply chain, production and delivery schedules are shared (SC process integration construct) and your SC trading partners are informed in advance about changing needs (SCV construct)

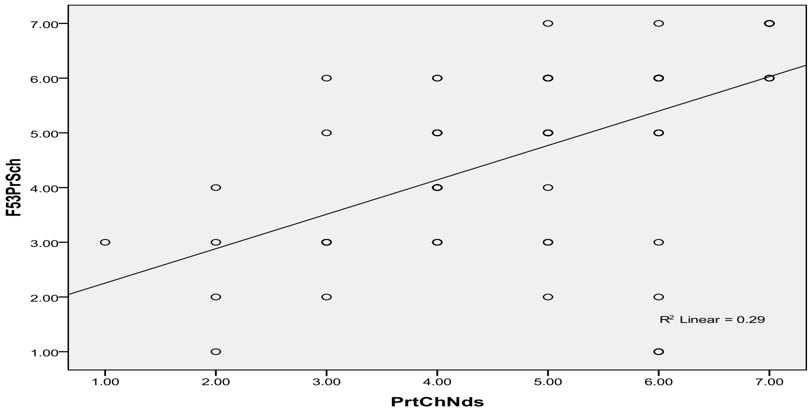


Figure 4: scatter diagram of the two investigated items
(..production and delivery schedule.. & ..changing needs…)

As depicted in figure 4, the first item which is related to sharing production and delivery schedule across SC (as an independent variable) could predict 29% of the variance in the second item which is concerned with informing SC trading partners in advance about changing needs (as a dependent variable). It can be deduced that the first item is a good predictor for the second item which is desired outcome. The ability of the predictor to explain 29% of the variance in the criterion variable is not large enough to raise significant concerns. In addition, this result is in line with the research findings that indicate that SC process integration is able to explain the largest amount of the variance in SCV (43.4 %), see p.282. Hence, the idea of overlapping among these two items is disregarded. Yet, further examination will be implemented in the following section.

b. Across your supply chain, production and delivery schedules are shared (SC process integration construct) and your SC trading partners share proprietary information with you (SCV construct)

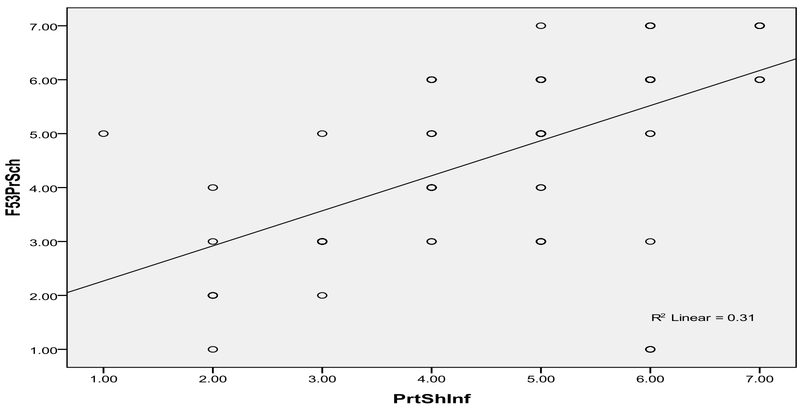


Figure 5: scatter diagram of the two investigated items

(..production and delivery schedule.. & ..proprietary information…)

Figure 5 shows the relationship between the ability to share production and delivery schedule across SC as the independent variable and the firm's ability to share proprietary information with SC trading partners as the criterion variable. The independent variable explains 31% of the variance in the dependent variable confirming that this independent variable is a good predictor. This result came in line with the related research findings confirming that SC process integration is a strong predictor for SCV. This percentage (31%) is a desired result that does not reveal overlapping between the two variables. Further analysis is considered in the following section for deeper investigation.

c. Across your supply chain, production and delivery schedules are shared (SC process integration construct) and your SC trading partners keep you fully informed about issues affecting your business

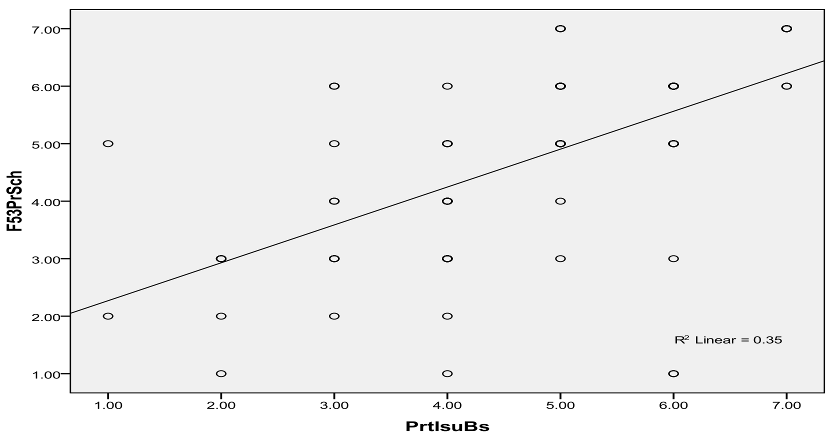


Figure 6: scatter diagram of the two investigated items

(..production and delivery schedule.. & ..issues affecting business…)

According to figure 6, the independent variable represented through the extent to which production and delivery schedule are shared across a firm's SC could explain 36% of the variance in the criterion variable (SC trading partners keep you fully informed about issues affecting your business). This percentage proves that the independent variable is strong enough to explain large amount of the variance in the dependent variable. This outcome is close to related research findings proving that SC process integration could explain 43% of the variance in SCV. Therefore, the concern of overlapping between these two items can be confirmed. More investigation is provided in the following section.

d. Across your supply chain, production and delivery schedules are shared (SC process integration construct) and your SC trading partners share business knowledge of core business processes with you (SCV construct)

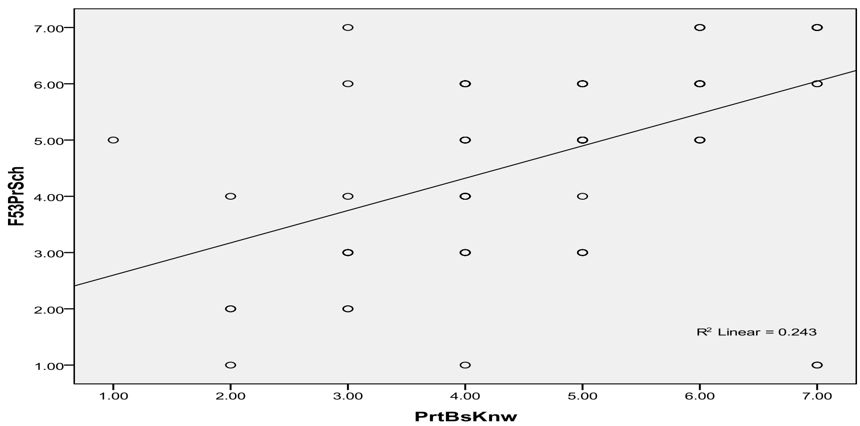


Figure 7: scatter diagram of the two investigated items
(..production and delivery schedule.. & ..business knowledge…)

The result presented in figure 7 demonstrates that the independent variable that is affiliated with SC process integration construct (Across your supply chain production and delivery schedules are shared) is able to predict 24% of the variance in the criterion item (your SC trading partners share business knowledge of core business processes with you). This percentage is relatively lower than the one related to SC process integration when regressed against SCV (43%). This result does not indicate overlapping between the two items. However, deeper investigation is performed using Chronbach's alpha in the following section.

e. Across your supply chain, production and delivery schedules are shared (SC process integration construct) and your SC trading partners and you exchange information that helps establishment of business planning (SCV construct)

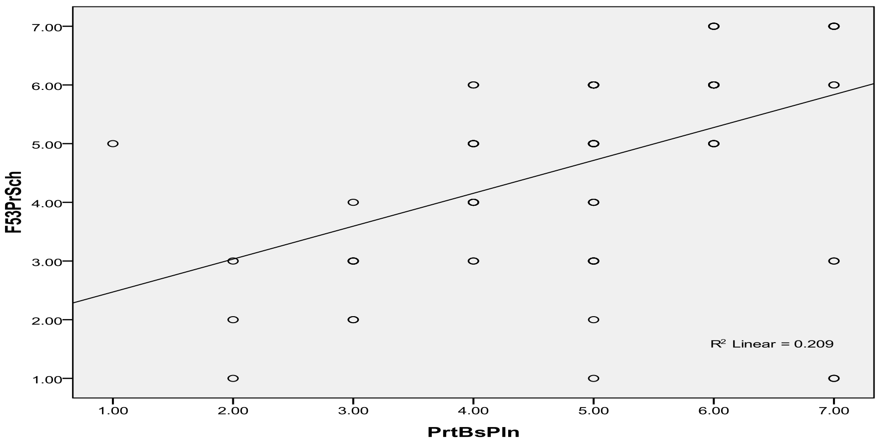


Figure 8: scatter diagram of the two investigated items (..production and delivery schedule.. & ..business planning…)

As seen in figure 7, the firm's ability to share production and delivery schedule across its SC as an independent variable could predict almost 21% of the variance in the criterion variable (your SC trading partners and you exchange information that helps establishment of business planning). This result indicates the lowest percentage this independent item could explain considering the other items forming SCV construct. Thus, no concern should be raised about the possibility of overlapping these two items. Yet, further examination is conducted in the following section.

f. Across your supply chain, production and delivery schedules are shared (SC process integration construct) and your SC trading partners and you inform each other about changes that may affect the other partners (SCV construct)

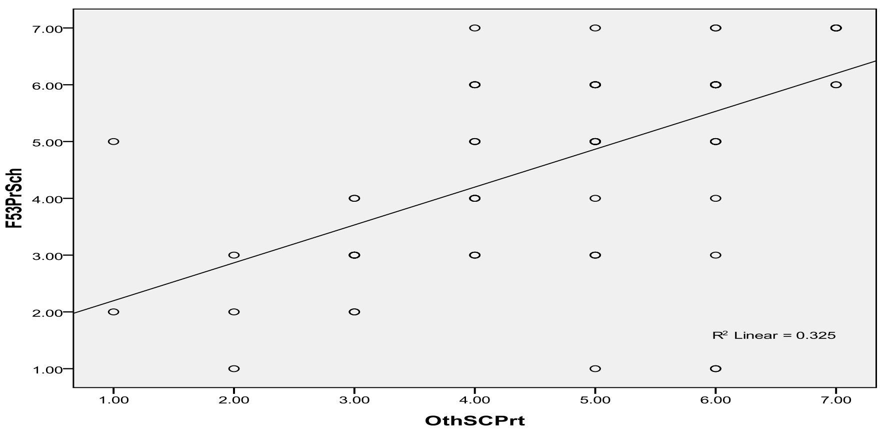


Figure 9: scatter diagram of the two investigated items (..production and delivery schedule.. & ..changes that may affect other partners …)

Figure 8 exhibited the relationship between the degree to which a firm shares its production and delivery schedule across its SC as independent variable affiliated with SC process integration construct and the extent to which a firm and its SC trading partners inform each other about changes that may affect the other partners as a criterion variable. The independent variable is strong enough to predict 32% of the changes in the criterion item. However, the amount of the variance explained is not large enough to demonstrate overlapping between these two items. Even though, additional examination is considered in the following section.

<u>Second item: Across your supply chain, performance metrics are shared (SC process integration construct)</u>

a. Across your supply chain, performance metrics are shared (SC process integration construct) and your SC trading partners are informed in advance about changing needs (SCV construct)

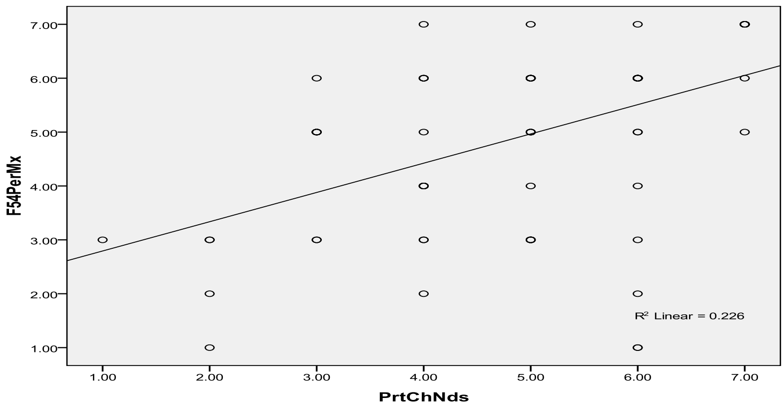


Figure 10: scatter diagram of the two investigated items
(..performance metrics.. & .. ..changing needs …)

Figure 10 illustrates the relationship between the extent to which performance metrics are shared across a firm's supply chain as an independent variable affiliated with SC process integration and the degree to which a firm informs in advance its SC trading partners about changing needs as a criterion variable. The independent variable could explain almost 23% of the variance in the dependent variable. This percentage is not alarming for overlapping between the two items. Even though, further investigation is considered in the following section.

b. Across your supply chain, performance metrics are shared (SC process integration construct) and your SC trading partners share proprietary information with you (SCV construct)

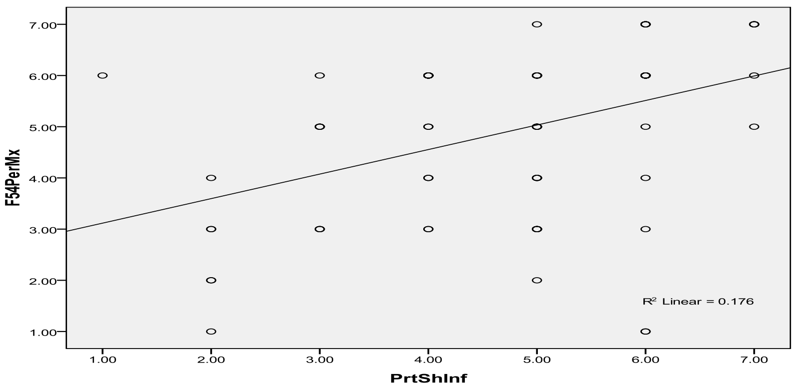


Figure 11: scatter diagram of the two investigated items (..performance metrics. & ..proprietary information…)

As presented in figure 11, the independent variable (across your supply chain performance metrics are shared is relatively a weak predictor of the dependent variable represented through the extent to which a firm's SC trading partners share proprietary information with it. The independent variable could only explain 18% of the changes in the dependent variable. This percentage is quite low compared to the one associated with SC process integration against SCV (43%). This result does not reflect overlapping between the two items. Despite, additional checking is performed in the following section.

c. Across your supply chain, performance metrics are shared (SC process integration construct) and your SC trading partners keep you fully informed about issues affecting your business (SCV construct)

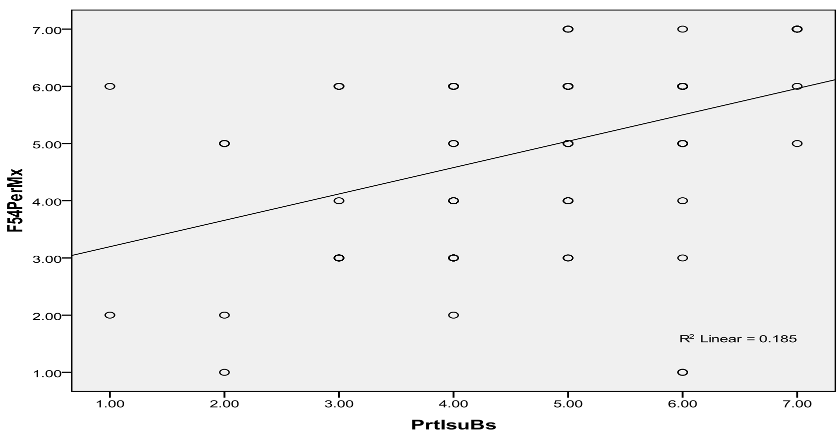


Figure 12: scatter diagram of the two investigated items (..performance metrics.. & ..issues affecting business…)

Figure 12 depicts similar pattern to the one presented in table 11. Same independent variable was only able to explain 19 % of the changes in the dependent variable (your

SC trading partners keep you fully informed about issues affecting your business). According to this result, no indication for overlapping exists between the two items. However, deeper investigation is still considered.

d. Across your supply chain, performance metrics are shared (SC process integration construct) and your SC trading partners share business knowledge of core business processes with you (SCV construct)

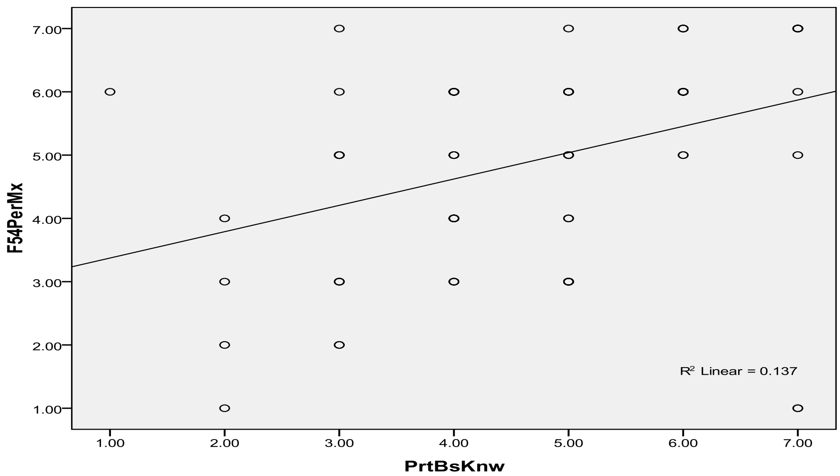


Figure 13: scatter diagram of the two investigated items (..performance metrics.. & ..business knowledge…)

Figure 13 exhibits the lowest prediction power of the same independent variable affiliated with SC process integration construct and the dependent item (your SC trading partners share business knowledge of core business processes with you) which is part of SCV construct. This independent variable only explains almost 14% of the variance in the criterion variable. This is an indication that this item is a weak predictor of the dependent item. It can be concluded that overlapping between the two items is not a real concern. However, further examination is still considered.

e. Across your supply chain, performance metrics are shared (SC process integration construct) and your SC trading partners and you exchange information that helps establishment of business planning (SCV construct).

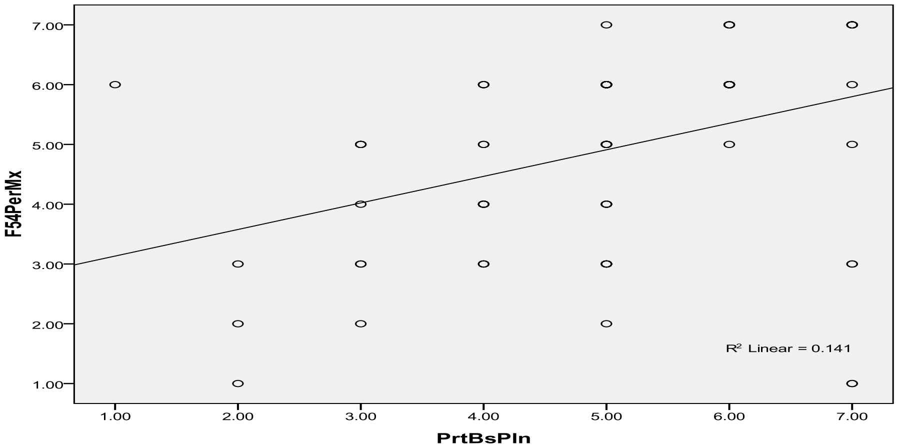


Figure 14: scatter diagram of the two investigated items (..performance metrics.. & ..business planning…)

Very similar result to the previous one (shown in figure 13) is illustrated in figure 14. The independent variable (across you SC performance metrics are shared) that is part of SC process integration construct could only explain 14% of the changes in the criterion item (your SC trading partners and you exchange information that helps establishment of business planning). This result is much lower compared to the explanation power of SC process integration on SCV as summated scales. Here, overlapping between the two items is not a concern. However, further investigation is still conducted.

f. Across your supply chain, performance metrics are shared (SC process integration construct) and your SC trading partners and you inform each other about changes that may affect the other partners (SCV construct)

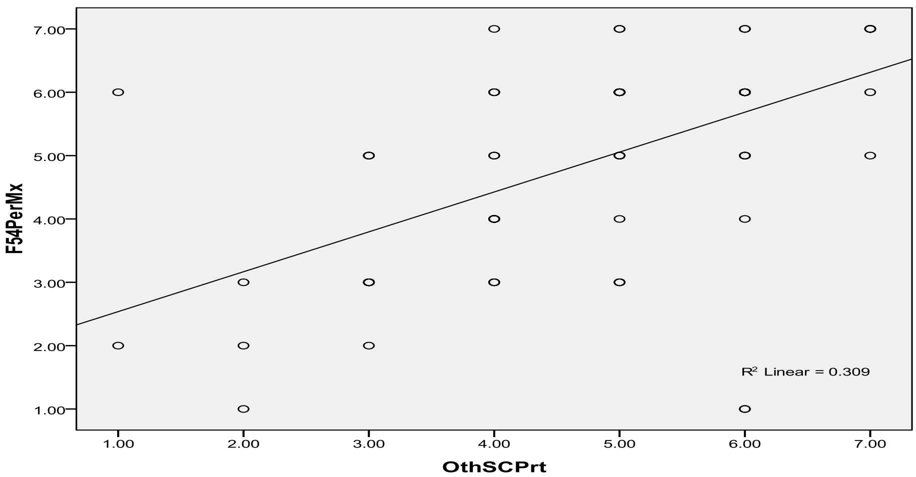


Figure 15: scatter diagram of the two investigated items (..performance metrics.. & ..changes that may affect other partners …)

Figure 15 demonstrates the largest amount the independent variable could explain in the variance of the investigated criterion variables. Here, the predictor (across your SC performance metrics are shared) could explain 31% of the changes in the dependent variable (your SC trading partners and you inform each other about changes that may affect the other partners). This result indicates that this independent variable is a good predictor to the independent variable. However, this percentage is not large enough to raise a concern about overlapping between the two constructs.

<u>Third item: Across your supply chain, SC members collaborate in arriving at demand forecasts (SC process integration construct)</u>

a. Across your supply chain, SC members collaborate in arriving at demand forecasts (SC process integration construct) and your SC trading partners are informed in advance about changing needs (SCV construct)

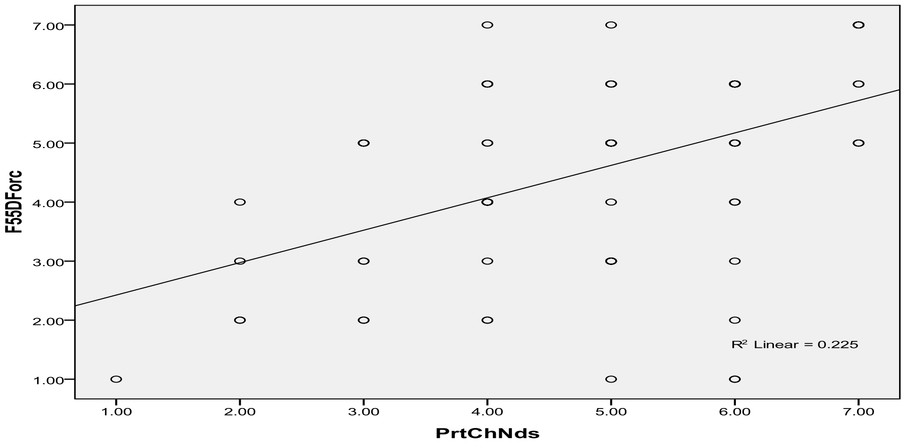


Figure 16: scatter diagram of the two investigated items (..demand forecasts.. & .. ..changing needs …)

Figure 16 provides the scatter plot and value of R^2 of the relationship between the independent variable (the extent to which SC members collaborate in arriving at demand forecasts) that is affiliated with SC process integration construct and the dependent variable representing SCV construct (your SC trading partners are informed in advance about changing needs). The independent variable could predict almost 23% of the variance in the dependent variable. This percentage does not reflect an overlapping problem between the two items. Yet, further checking is considered using Chronbach's alpha.

b. Across your supply chain, SC members collaborate in arriving at demand forecasts (SC process integration construct) and your SC trading partners share proprietary information with you (SCV construct)

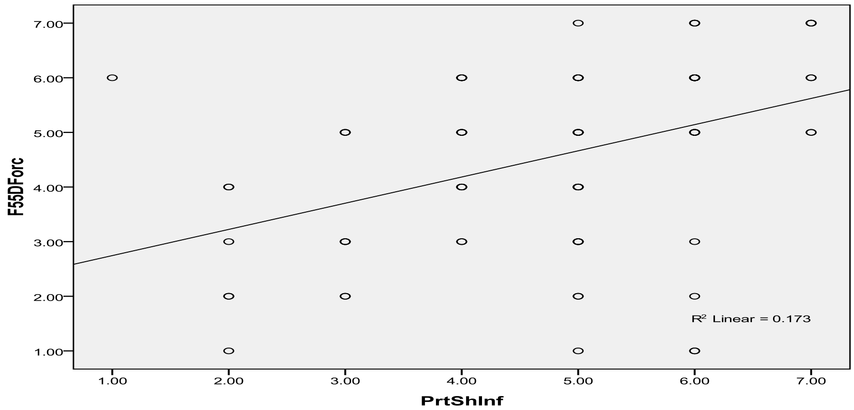


Figure 17: scatter diagram of the two investigated items
(..demand forecasts.. & ..proprietary information…)

As seen in figure 17, the independent variable **(**across your supply chain, SC members collaborate in arriving at demand forecasts) is only able to predict 17% of the variance in the criterion variable (your SC trading partners share proprietary information with you). This value is limited to indicate overlapping between the two items. However, further testing is conducted in the next section.

c. Across your supply chain, SC members collaborate in arriving at demand forecasts (SC process integration construct) and your SC trading partners keep you fully informed about issues affecting your business (SCV construct)

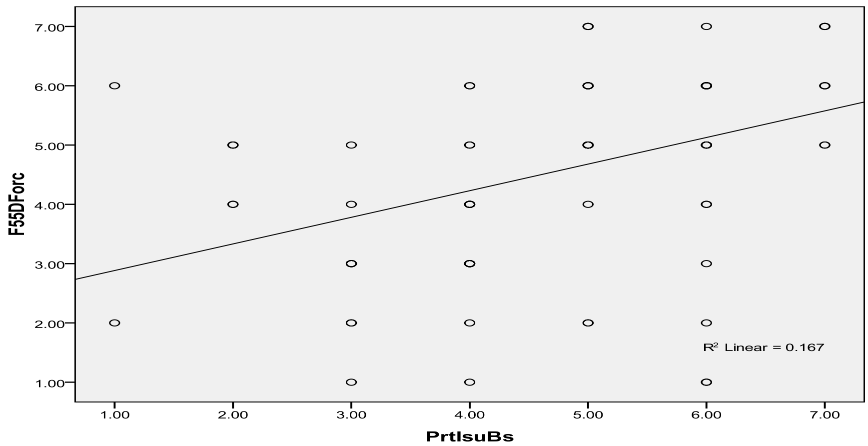


Figure 18: scatter diagram of the two investigated items
(..demand forecasts.. & ..issues affecting business…)

As presented in figure 18, R^2 value is almost 17% between the predictor **(**across your supply chain, SC members collaborate in arriving at demand forecasts) and the criterion variable (your SC trading partners keep you fully informed about issues affecting your business). As previously mentioned, this result is limited to indicate overlapping between the two items. Yet, further investigation is performed in the next section.

d. Across your supply chain, SC members collaborate in arriving at demand forecasts (SC process integration construct) and your SC trading partners share business knowledge of core business processes with you (SCV construct)

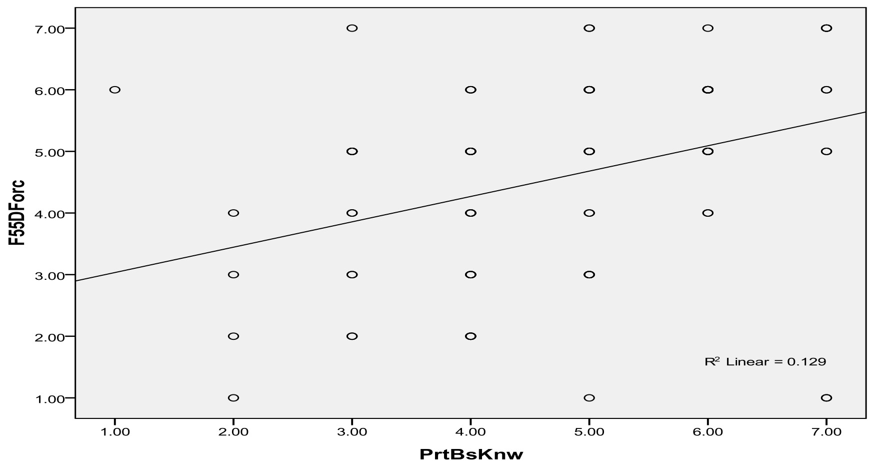


Figure 19: scatter diagram of the two investigated items (..demand forecasts.. & ..business knowledge…)

R^2 value, as presented in figure 19, is almost 13% between the predictor variable **(**across your supply chain, SC members collaborate in arriving at demand forecasts) and the criterion variable (your SC trading partners share business knowledge of core business processes with you). This value is quite limited to raise a concern about potential overlapping between the two variables. However, further investigation is implemented in the following section.

e. Across your supply chain, SC members collaborate in arriving at demand forecasts (SC process integration construct) and your SC trading partners and you exchange information that helps establishment of business planning (SCV construct).

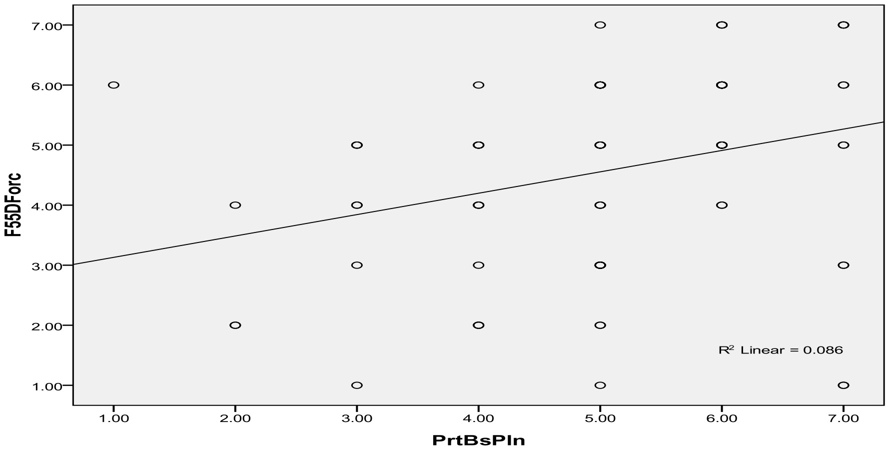


Figure 20: scatter diagram of the two investigated items
(..demand forecasts.. & ..business planning…)

As presented in figure 20, the R^2 value between the independent variable (across your supply chain, SC members collaborate in arriving at demand forecasts) and the criterion variable (your SC trading partners and you exchange information that helps establishment of business planning) is 9%. This value is quite limited and refers to a weak predictor. According to this result, the potential overlapping is not confirmed. Yet, additional investigation is performed.

f. Across your supply chain, SC members collaborate in arriving at demand forecasts (SC process integration construct) and your SC trading partners and you inform each other about changes that may affect the other partners (SCV construct)

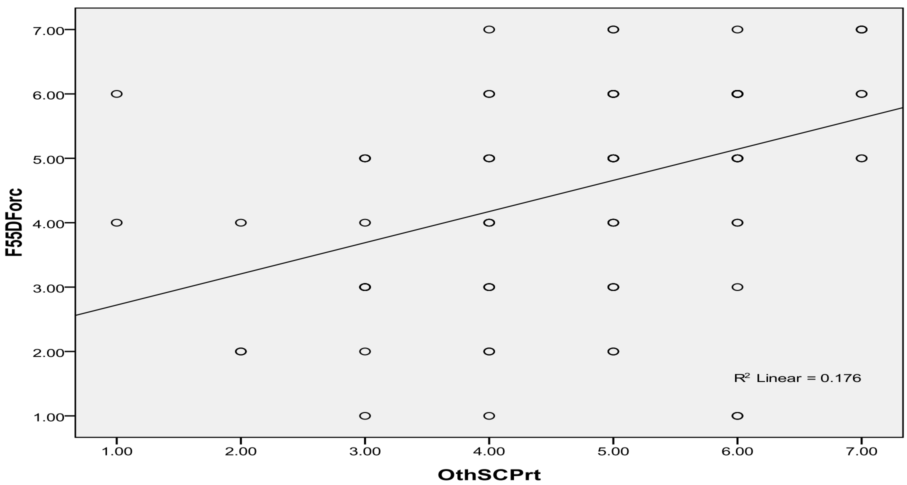


Figure 21: scatter diagram of the two investigated items
(..demand forecasts.. & ..changes that may affect other partners …)

The R^2 value, as presented in figure 21, shows that the independent variable (across your supply chain, SC members collaborate in arriving at demand forecasts) was able to predict almost 18% of the variance in the dependent variable (your SC trading partners and you inform each other about changes that may affect the other partners). This percentage is not sufficient to reflect any overlapping between the two items. Yet, further examination is conducted in the next section.

<u>Fourth item: Across your supply chain, .demand levels are visible (SC process integration construct)</u>

a. Across your supply chain, demand levels are visible (SC process integration construct) and your SC trading partners are informed in advance about changing needs (SCV construct)

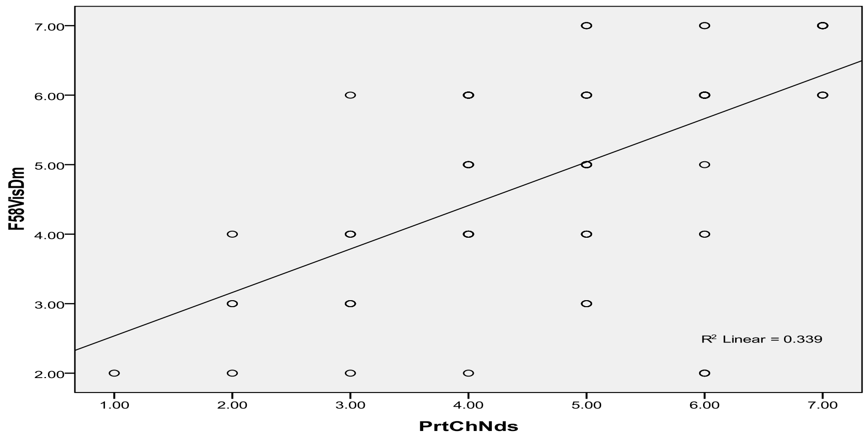


Figure 22: Scatter diagram of the two investigated items
(..demand levels.. & .. ..changing needs …)

As depicted in figure 22, the independent variable (across your supply chain, demand levels are visible) that is affiliated with SC process integration construct was able to predict almost 34% of the variance in the criterion variable (your SC trading partners are informed in advance about changing needs). This result illuminates that the independent variable is a good predictor for the dependent variable. However, 34% is not large enough to raise a concern about the possibility of overlapping between the two items. As a way of triangulation, another statistical technique is employed to validate this result.

b. Across your supply chain, demand levels are visible (SC process integration construct) and your SC trading partners share proprietary information with you (SCV construct)

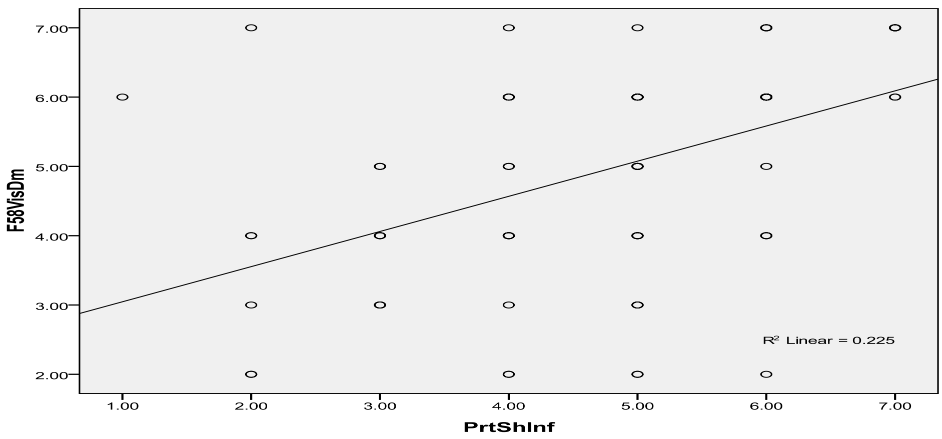


Figure 23: scatter diagram of the two investigated items (..demand levels.. & ..proprietary information…)

The R^2 value, as exhibited in figure 23, is almost 23% between the independent variable (across your supply chain, demand levels are visible) and the dependent variable (your SC trading partners share proprietary information with you). This means that the independent variable is able to explain 23% of the variance in the criterion variable. This percentage does not raise any concern about the possibility of overlapping between the two items. Even though, additional examination is considered in the following section.

c. Across your supply chain, demand levels are visible (SC process integration construct) and your SC trading partners keep you fully informed about issues affecting your business (SCV construct)

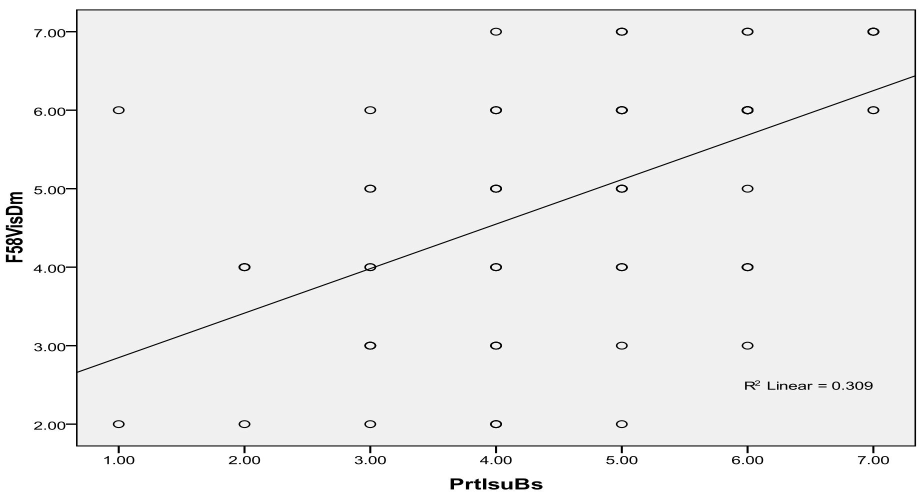


Figure 24: scatter diagram of the two investigated items (..demand levels.. & ..issues affecting business…)

Figure 24 introduces the scatter plot and R^2 value of the relationship between the independent variable affiliated with SC process integration construct (across your supply chain, demand levels are visible) and the dependent variable as part of SCV construct (your SC trading partners keep you fully informed about issues affecting your business). The independent variable was able to explain approximately 31% of the changes in the dependent variable. This percentage is not large enough to reflect overlapping between the two items.

d. Across your supply chain, demand levels are visible (SC process integration construct) and your SC trading partners share business knowledge of core business processes with you (SCV construct)

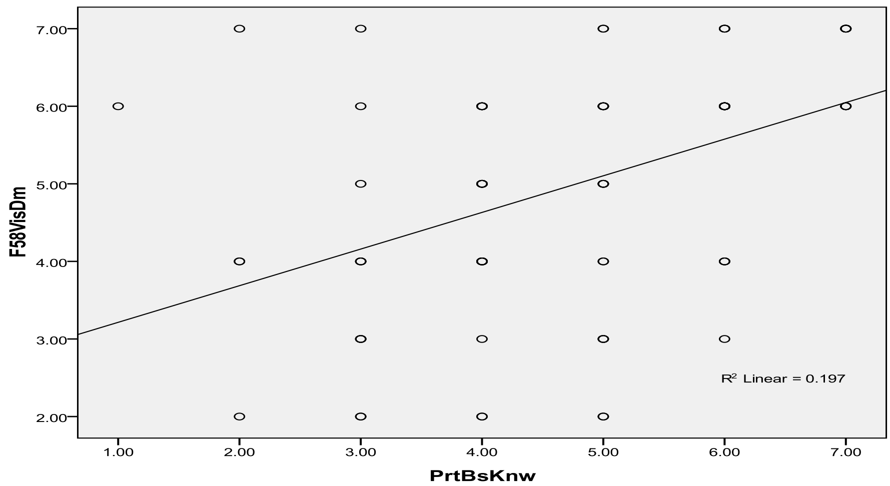


Figure 25: scatter diagram of the two investigated items (..demand levels.. & ..business knowledge…)

According to figure 25, the independent variable representing SC process integration (across your supply chain, demand levels are visible) is able to explain almost 20% of the changes in the dependent variable (your SC trading partners share business knowledge of core business processes with you). This percentage is quite limited to deduce overlapping between the two items. However, further investigation is performed in the following section.

e. Across your supply chain, demand levels are visible (SC process integration construct) and your SC trading partners and you exchange information that helps establishment of business planning (SCV construct)

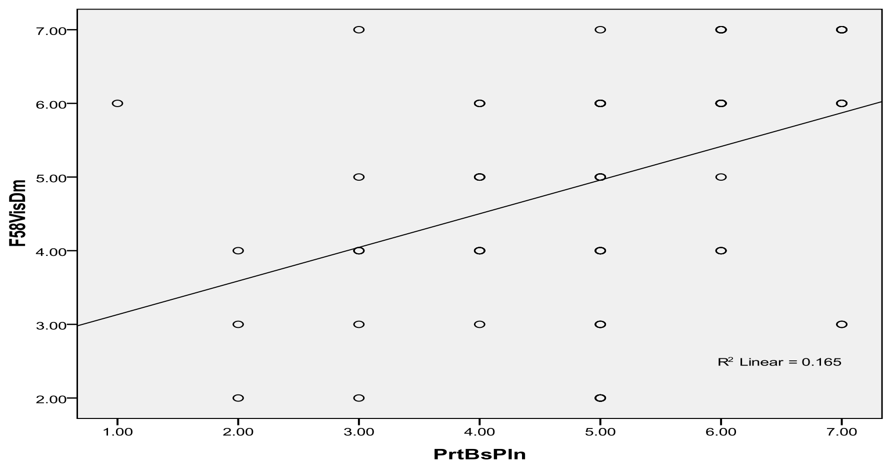


Figure 26: scatter diagram of the two investigated items (..demand levels.. & ..business planning…)

As seen in figure 26, the R^2 value is almost 17% between the independent variable affiliated with SC process integration (across your supply chain, demand levels are visible) and the criterion variable (you and your SC trading partners and you exchange information that helps establishment of business planning). This illuminates that the independent variable could explain 17% of the variance in the dependent variable. This percentage does not indicate overlapping between the two items. To validate this conclusion, further analysis is implemented in the next section.

f. Across your supply chain, demand levels are visible (SC process integration construct) and your SC trading partners and you inform each other about changes that may affect the other partners (SCV construct)

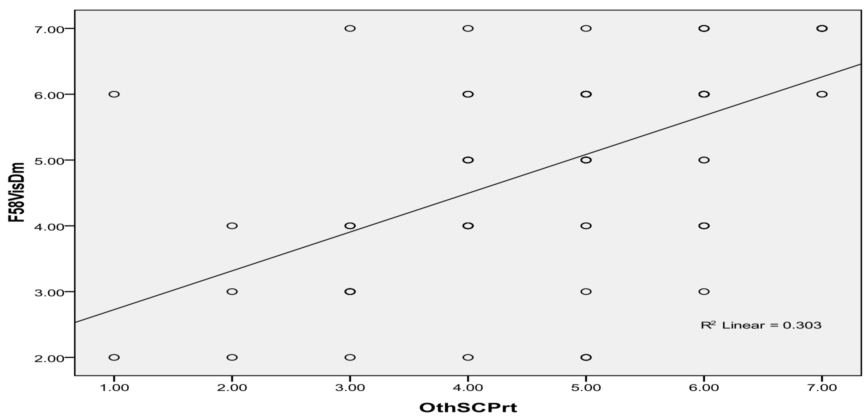


Figure 27: scatter diagram of the two investigated items (..demand levels.. & ..changes that may affect other partners …)

The R^2 value as presented in figure 27 is approximately 30% between the independent variable within SC process integration construct (across your supply chain, demand levels are visible) and the criterion variable within SCV construct (your SC trading partners and you inform each other about changes that may affect the other partners). Therefore, the predictor variable is strong enough to explain 30% of the variance in the dependent variable. This prediction power is not that large to reflect overlapping between the two items. Additional investigation is conducted in the following section.

Fifth item: Across your supply chain, inventory data are visible at all stages (SC process integration construct)

a. Across your supply chain, inventory data are visible at all stages (SC process integration construct) and your SC trading partners are informed in advance about changing needs (SCV construct)

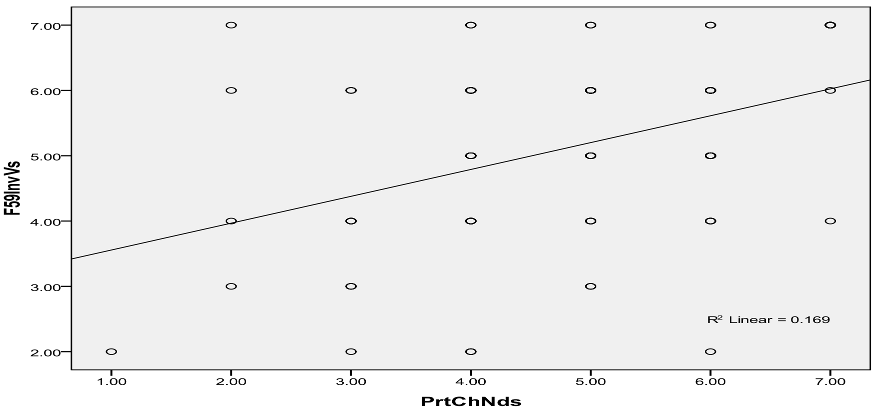


Figure 28: scatter diagram of the two investigated items (..inventory data.. & .. ..changing needs …)

As illustrated in figure 28, the R^2 value is almost 17% between the independent variable within SC process integration construct (across your supply chain, inventory data are visible at all stages) and the criterion variable within SCV construct (SC trading partners are informed in advance about changing needs). Thus, the predictor variable was able to explain 17% of the variance in the dependent variable. This percentage is quite limited to infer overlapping between the two items. To validate this conclusion, further examination is conducted in the following section.

b. Across your supply chain, inventory data are visible at all stages (SC process integration construct) and your SC trading partners share proprietary information with you (SCV construct)

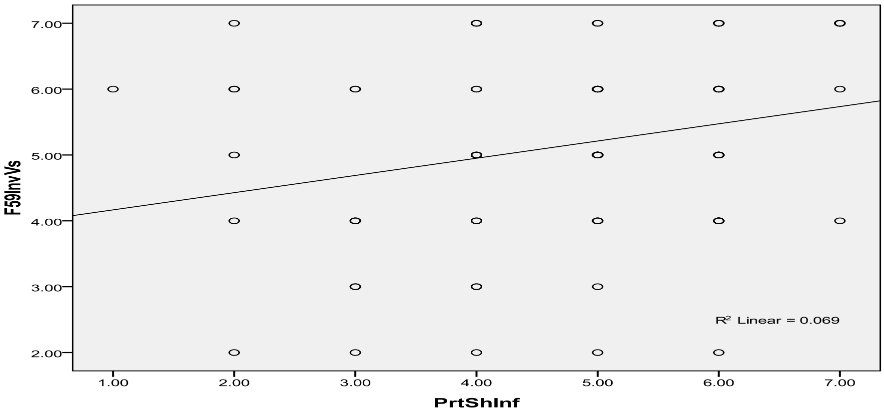


Figure 29: scatter diagram of the two investigated items (..inventory data.. & ..proprietary information…)

The result of R^2 as seen in figure 29 reveals that the predictor variable representing SC process integration construct (across your supply chain, inventory data are visible at all stages) is able to explain almost 7% of the changes in the criterion variable within SCV construct (your SC trading partners share proprietary information with you). This percentage is quite low to reflect overlapping between the two items. Even though, additional examination is considered to validate this conclusion.

c. Across your supply chain, inventory data are visible at all stages (SC process integration construct) and your SC trading partners keep you fully informed about issues affecting your business (SCV construct).

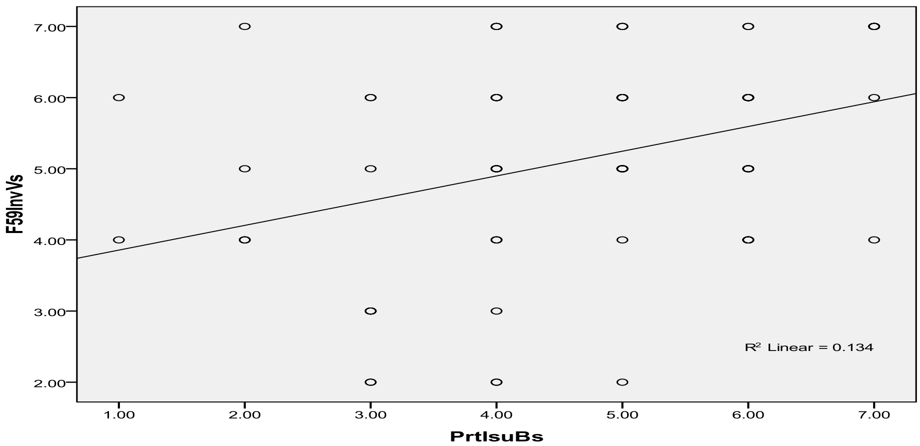


Figure 30: scatter diagram of the two investigated items (..inventory data.. & ..issues affecting business…)

As depicted in figure 30, the R^2 value is almost 13%. This result indicates that the independent variable within SC process integration construct (across your supply chain, inventory data are visible at all stages) was able to explain 13% of the variance in the criterion variable affiliated with SCV construct (your SC trading partners keep you fully informed about issues affecting your business). This percentage is not large enough to raise any concern about the possibility of overlapping between the two items. Yet, further examination is conducted for validation purpose.

d. Across your supply chain, inventory data are visible at all stages (SC process integration construct) and your SC trading partners share business knowledge of core business processes with you (SCV construct).

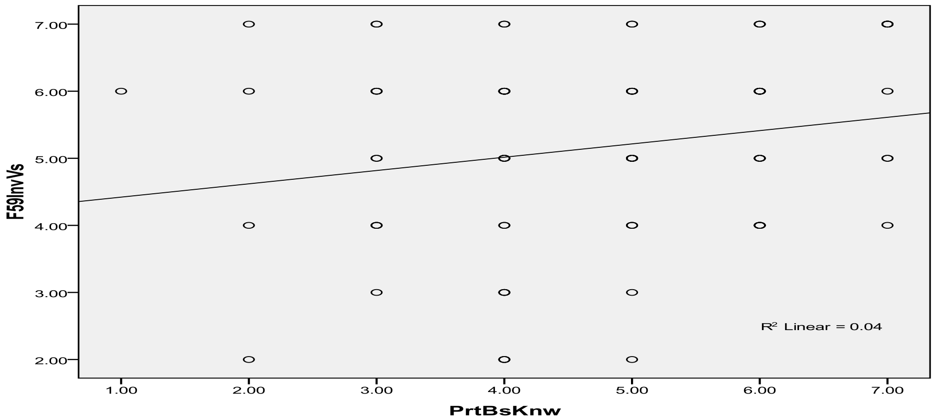


Figure 31: scatter diagram of the two investigated items (..inventory data.. & ..business knowledge…)

Figure 31 depicts the relationship between the predictor variable within SC process integration construct (across your supply chain, inventory data are visible at all stages) and the dependent variable within SCV construct (your SC trading partners share business knowledge of core business processes with you). The predictor variable could explain only 4% of the variance in the criterion variable that indicate weak relationship. According to R^2 value, no overlapping between the two variables can be inferred. In the following section, further examination is performed.

e. Across your supply chain, inventory data are visible at all stages (SC process integration construct) and your SC trading partners and you exchange information that helps establishment of business planning (SCV construct)

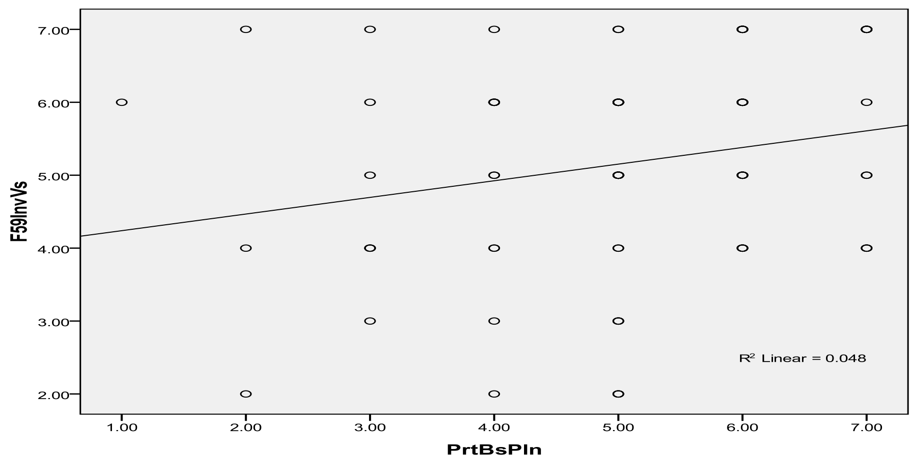


Figure 32: scatter diagram of the two investigated items (..inventory data.. & ..business planning…)

As exhibited in figure 32, the independent variable (across your supply chain, inventory data are visible at all stages) could only explain almost 5% of the variance in the criterion variable (your SC trading partners and you exchange information that helps establishment of business planning). This R^2 value indicates a weak predictor of the dependent variable that in turn, does not support the idea of overlapping between the two items. Triangulation is considered to validate this result.

f. Across your supply chain, inventory data are visible at all stages (SC process integration construct) and your SC trading partners and you inform each other about changes that may affect the other partners (SCV construct).

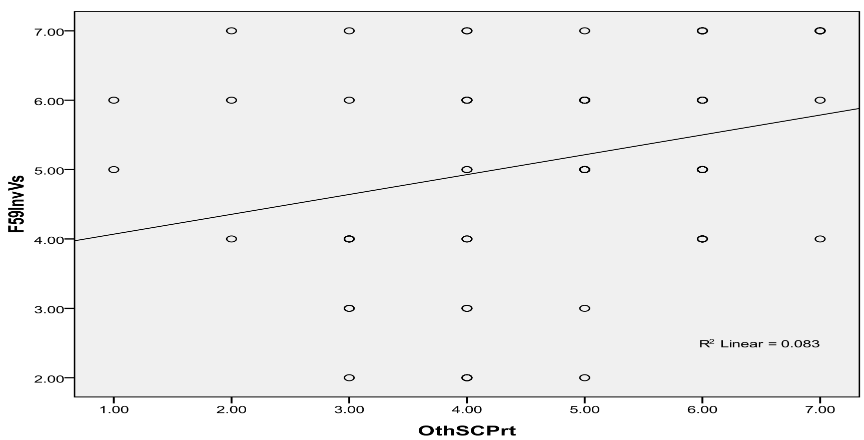


Figure 33: scatter diagram of the two investigated items (..inventory data.. & ..changes that may affect other partners …)

According to figure 33, the same independent variable (within SC process integration construct) has small effect on the criterion variable within SCV construct (your SC trading partners and you inform each other about changes that may affect the other partners). The predictor variable was only able to explain almost 8% of the changes in the dependent variable. Therefore, no concern should be raised about the possibility of overlapping between the two items. However, additional, investigation is considered in the following section.

To conclude, upon checking the R^2 value of the relationships between each of the investigated items (five items) within SC process integration construct and each of the suggested problematic items (6 items) within SCV construct, none of these values was extremely large to indicate overlapping problem. The R^2 values of the examined thirty relationships (5 x 6) range between .04 and .36; see table 13.

Table 13: R^2 values for the examined relationships (SC process integration vs. SCV)

Your supply chain trading partners…	…are informed in advance about changing needs	..share proprietary information with you	..keep you fully informed about issues affecting your business	..share business knowledge of core business processes with you	..and you exchange information that helps establishment of business planning	..and you inform each other about changes that may affect the other partners
Across your supply chain.. ..production and delivery schedules are shared	.29	.31	<u>.36</u>	.24	.21	.33
..performance metrics are shared	.23	.18	.19	.14	.14	.31
..SC members collaborate in arriving at demand forecasts	.23	.17	.17	.13	.09	.18
..demand levels are visible	.34	.23	.31	.20	.17	.30
..inventory data are visible at all stages	.17	.07	.13	<u>.04</u>	.05	.08

4. *To check the value of Chronbach's alpha if item deleted*

The construct under investigation is supply chain visibility as the dependent variable that incorporates some items suggested to overlap with other items within supply chain process integration construct. This section provides the results of the Chronbach's alpha values after adding the suggested five overlapped items. These items incorporate *across your supply chain production and delivery schedules are shared, performance metrics are shared, SC members collaborate in arriving at demand forecasts, demand levels are visible, and inventory data are visible at all stages*. More interest is in the value of Chronbach's alpha when these items are deleted from the construct.

a. Across your supply chain production and delivery schedules are shared

Table 14: Reliability Statistics

Cronbach's Alpha	N of Items
.966	15

Table 15: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Across your supply chain… production and delivery schedules are shared	68.1392	262.250	.681	.966

Table 14 demonstrates that the value of Chronbach's alpha when a new item is added (across your supply chain production and delivery schedules are shared) to supply chain visibility construct becomes .966. Although this value confirms high reliability of this construct as it is greater than .7, table 15 illuminates that the deletion of the added item resulted in the same value of Chronbach's alpha (.966). This result proves that this item might affiliate with SCV construct and in turn may support the idea of overlapping between this item and SCV construct. Hence, further investigation is conducted in the next section to check the effect of this item on the result of the regression model.

b. Across your supply chain, performance metrics are shared

Table 16: Reliability Statistics

Cronbach's Alpha	N of Items
.963	15

Table 17: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Across your supply chain, performance metrics are shared	67.9872	263.805	.533	.966

Table 16 indicates the value of Chronbach's alpha (.963) for supply chain visibility construct upon the inclusion of the investigated item (across your supply chain, performance metrics are shared). Table 17 illustrates an increase in the value of Chronbach's alpha (.968) upon the deletion of the new item. This item is originally part of SC process integration construct as an independent variable within the research model. This outcome reveals that this item diminishes the reliability of SCV construct. This finding validates other results that indicated no concern should be raised about the overlapping between this item and SCV construct. Consequently, no more investigation is required.

c. Across your SC, SC members collaborate in arriving at demand forecasts

Table 18: Reliability Statistics

Cronbach's Alpha	N of Items
.961	15

Table 19: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Across your SC, SC members collaborate in arriving at demand forecasts	68.0370	256.111	.515	.964

As depicted in table 18, the Chronbach's alpha value of the SCV construct after the addition of a new item (across your SC, SC members collaborate in arriving at demand forecasts) is .961 demonstrating high reliability of this construct. Table 19 highlights an enlargement in this value to become.964 when the added item that is originally affiliated with SC process integration construct is removed from the construct. This result verifies that this added item is not part of SCV construct that validate the previously mentioned results. Thus, no further examination is required.

d. Across your SC, demand levels are visible

Table 20: Reliability Statistics

Cronbach's Alpha	N of Items
.964	15

Table 21: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Across your supply chain, demand levels are visible	68.0370	256.111	.621	.964

Table 20 exhibited the Chronbach's alpha value of the SCV construct after the inclusion of a new item (across your SC, demand levels are visible) that is originally affiliated with SC process integration construct. This value is .964 that confirms high reliability of this construct. Table 21 demonstrates that the value of Chronbach's alpha has not been changed upon the deletion of the added item i.e. α = .964. This result may raise a concern about the existence of overlapping problem between this item and SCV construct. Further investigation is considered in the following section to address the effect of this result on the regression model.

e. Across your SC, inventory data are visible at all stages

Table 22: Reliability Statistics

Cronbach's Alpha	N of Items
.961	15

Table 23; Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Across your SC, inventory data are visible at all stages	68.0370	256.111	.441	.964

As presented in figure 22, the value of Chronbach's alpha of SCV construct upon the inclusion of a new item (across your SC, inventory data are visible at all stages) that is originally part of SC process integration construct is .961. this value proves high reliability of SCV construct. Table 23 illuminates that when the added item is removed from SCV construct the Chronbach's alpha value has jumped up to become .964. This result proves that the added item is not affiliated to SCV construct that in turn, validate other study findings that reached the same conclusion. Therefore, no further investigation is needed.

To conclude, the investigation of the concern raised about the possibility of overlapping between some items of SCV construct and other items within supply chain process integration construct has been tested using various statistical techniques. The findings of this investigation reveals that among five items of SC process integration construct as an independent variable , only two items may indicate overlapping based on Cronbach's alpha value if item deleted. These two items incorporate "*across your supply chain production and delivery schedules are shared* (conduct tables 14 & 15), *and demand levels are visible* (see tables 20 & 21)*"*. An item is a part of a construct when the deletion of this item diminishes the value of Chronbach's alpha (Pallant, 2007). According to the study's findings, the inclusion of these two items within SCV construct showed indifferent impact on Chronbach's alpha value. In addition, the R^2 values of these two items, affiliated with SC process integration, in relation with the other six items within SCV construct were relatively the highest values compared to other investigated SC process integration items, see table 13. However, the highest value of R^2 was .36 that does not reflect an overlapping concern. However, the study still considers testing the effect of these two items on the research model.

The regression model considering the removal of the two problematic items.

The outcome of the previous step shows that two items of SC process integration construct may be part of SCV construct, therefore the multiple regression model is retested based on deleting these two items from the model to check its impact on R^2 value. Table 24 presents a summary of the new model.

Table 24: The new Model Summary[c]

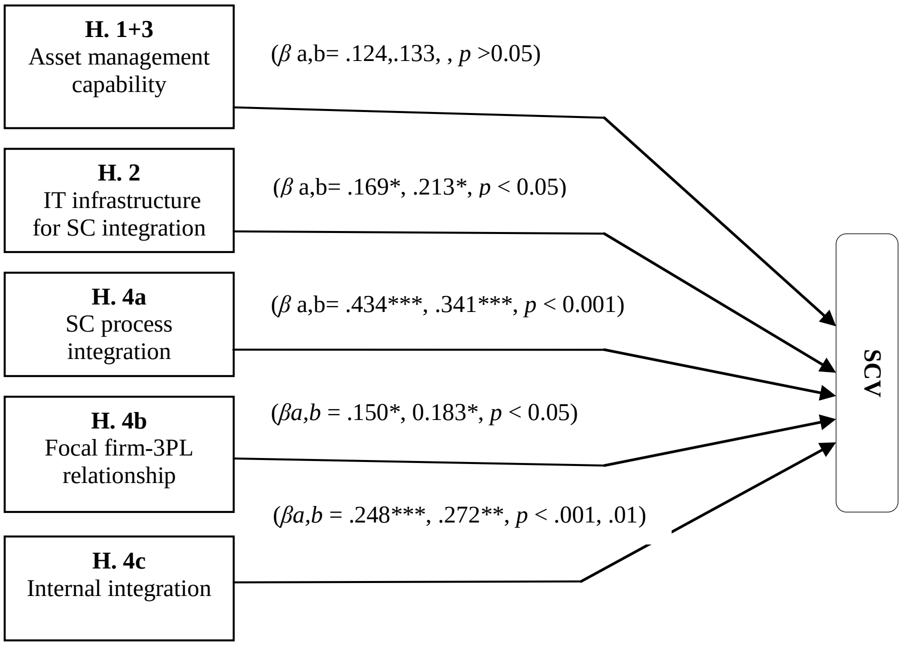
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.252[a]	.063	-.023	16.19015	.063	.729	5	54	.604	
2	.845[b]	.715	.656	9.37976	.651	22.377	5	49	.000	2.192

a. Predictors: (Constant), Firm size1, IndsTyp2, IndsTyp3, IndsTyp1, IndsTyp4

b. Predictors: (Constant), Firm size1, IndsTyp2, IndsTyp3, IndsTyp1, IndsTyp4, Viva SCprInteg F53&58 deleted, Total Tracking process, Total intra-firm relationships, Total LSP, Total IT infrastructure

c. Dependent Variable: Total Supply chain visibility

Figure 33 provides a comparison between the findings of the original regression model and the new model (before and after the deletion of the specified two items). As depicted in figure 33, the deletion of the two items that may cause overlapping with SCV construct does not affect the results of the multiple regression model significantly. The value of overall R^2 has increased only slight from .706 to .715. In addition, R^2 change value has slightly increased from .650 to .651. Moreover, the Adjusted R^2 value from .674 to .656. Since the changes in the explanatory power of the model has not changed significantly, there is no need to remove these two items from the model. In addition, Adjusted R^2 value is an important indicator for the cross-validity of the model (Field, 2005). To reiterate, the closer the Adjusted R^2 value to the R^2 the better is the cross-validity of the model. As illustrated in figure 33, the original model has smaller gap between the adjusted R^2 value and R^2 (.674 to .706) whereas, the new model has a larger gap between the two values (.656 to .715). Furthermore, "*F-ratio indicates the ratio of the improvement in prediction as a result of fitting the model relative to the inaccuracy that still exists in the model*" (Field, 2005). According to figure 33, the overall model F for the original model (model 2a) is almost twice that of the new model (model 2b) - 40.233 compared to 22.377. This proves that the goodness of fit of the original model is much higher than the new model. As such, the original model appears to be more robust.



	Model1a	Model1b	Model2a	Model2b
Firm size (β)	-0.151	-.169	-0.168**	-.197
Industry type1 (β)	0.041	.049	.008	.031
Industry type2 (β)	.088	.093	-.007	-.017
Industry type3(β)	-.105	-.102	-.120	-.124
Industry type4 (β)	.082	.085	.011	-.002
ΔR^2	0.056	.063	.650***	.651***
Overall R^2	0.056	.063	0.706	.715
Adjusted R^2	0.007	-.023	0.674	.656
Overall model F	1.140	.729	40.233***	22.377***

Figure 33: Regression asset visibility capabilities to SCV
Note: significance at: *p, 0.05, * *p, 0.01, and * * *p, 0.001.

The implication and the recommendation of the overlapping concern between SCV and SC integration constructs.

Based on conducting four different statistical techniques, the proposed overlapping concern of the two items affiliated with SC process integration on the SCV construct has not been proven to cause a problem in the regression model. As a way of maintaining the quality of data collection in this research specifically construct validity, the study had to use valid measures from other studies. However, more academic work is needed in the areas of SC visibility (mainly information sharing as a sub-construct) and SC integration to clearly differentiate the two constructs in a way that removes any source of potential overlap. This might require re-wording, re-phrasing, re-structuring, and/or combining some of the currently used measures. This recommendation is already made in the thesis, see section 8.8.4, p. 359.

Third, IT infrastructure for SC integration and SCV constructs

IT infrastructure for SC integration as an independent variable incorporates cross functional SCM application system integration as a sub-construct which combines four items. Two of these items might overlap with the items pertaining to the level of information quality as a sub-construct of SCV. The two items are: in your *supply chain planning applications are able to be communicated in real time and transaction applications are able to be communicated in real time.* The level of information quality as a sub-construct of SCV has two items seen to be problematic with the previous two items including: *information exchange between you and your supply chain trading partners is timely and up to date.*

To examine the overlapping concern between the two construct, the study follows the aforementioned procedures.

1. ***The descriptive data for the investigated items of asset management capability and SCV***

Table (25) Suggested overlapped items within IT infrastructure construct

	Range	Min	Max	Mean	S.D.	Mode
In your supply chain..						
..planning applications are able to be communicated in real time	6.00	1.00	7.00	4.6180	1.67539	4.00
..transaction applications are able to be communicated in real time	6.00	1.00	7.00	4.7614	1.58291	5.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

Table (26) Suggested overlapped items within SCV construct

	Range	Min	Max	Mean	S.D.	Mode
Information exchange between your supply chain trading partners and you is.. ..timely	5.00	2.00	7.00	4.7407	1.35810	6.00
..up to date	5.00	2.00	7.00	4.8642	1.29183	6.00

Note: Min: minimum, Max: maximum, S.D.: standard deviation

As depicted in table 25 and 26, the results indicate relative similarity between the means of the independent variable items representing IT infrastructure for SC integration and the items affiliated with SCV as the criterion variable.

The mean of the item related to *planning applications are able to be communicated in real time across a supply chain* that is affiliated with IT infrastructure for SC integration is 4.62, see table 25. The mean of the second item (*transaction applications are able to be communicated in real time across a SC*) within IT infrastructure construct is 4.76, see table 25. These values of the two items are closer to somewhat agreement among respondents. On the other hand, the means of the suggested problematic items within SCV construct (*information exchange… is timely, and up to date*) are 4.74 and 4.86 respectively, see table 26. This result illustrates more inclination towards relative agreement among respondents.

According to the descriptive results, overlapping between the IT infrastructure and SCV constructs may be a concern. Further investigation is conducted in the next section using bivariate correlation.

2. ***Findings of the bivariate correlation analysis between the suggested overlapped items within IT infrastructure for SC integration as independent variable and supply chain visibility as dependent variable***

Table (27) Bivariate correlation among suggested overlapped items

Information exchange between your supply chain trading partners and you is..	..timely	..up to date
In your supply chain.. ..planning applications are able to be communicated in real time	.496**	.504**
..transaction applications are able to be communicated in real time	.389**	.394**

(**) Correlation is significant at the 0.01 level

As shown in table 27, collinearity problem does not exist (as all R values are < 0.8) between the items constituting IT infrastructure for SC integration as the independent variable and the items forming supply chain visibility as the dependent variable. The largest significant *R* value is 0.504 which is much lower than 0.8. This came in line with the study findings that illuminated significant high correlation (*R* = 0.60) between IT infrastructure for SC integration and supply chain visibility, see p. 207-08. Therefore, according to the correlation findings, no concern need to be raised about the possibility of overlapping between the investigated items. More investigation is conducted in the following section using scatter plots and linear regression.

3. ***The scatter plots and R^2 linear to show the degree to which each pair of items under investigation (IT infrastructure for SC integration items and SCV items) is powerful in predicting each other;***

a. In your supply chain planning applications are able to be communicated in real time (IT infrastructure construct) and information exchange is timely (SCV construct)

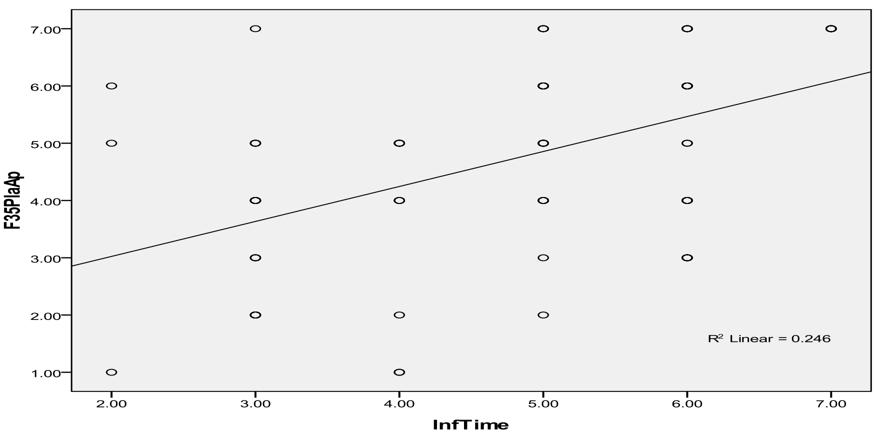


Figure 34: scatter diagram of the two investigated items (planning applications & timely information)

The R² value, as exhibited in figure 34, is 24% between the independent variable (in your supply chain planning applications are able to be communicated in real time) and the dependent variable (Information exchange between your supply chain trading partners and you is timely). This means that the independent variable is able to explain 24% of the variance in the criterion variable. This percentage does not raise any concern about the possibility of overlapping between the two items. This will be examined again using different technique in the following section.

b. In your supply chain planning applications are able to be communicated in real time (IT infrastructure construct) and information exchange is up to date (SCV construct)

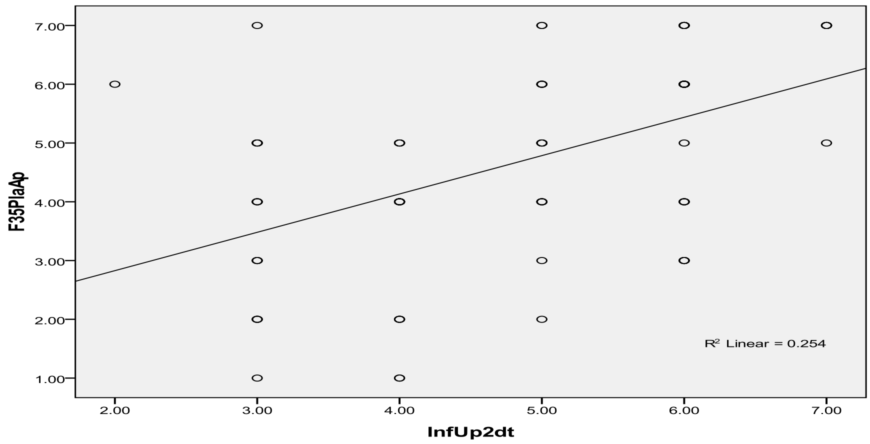


Figure 35: scatter diagram of the two investigated items (planning applications & up to date information)

According to figure 35, the independent variable affiliated to IT infrastructure construct (in your supply chain planning applications are able to be communicated in real time) was able to predict 25% of the variability in the criterion variable within SCV construct (information exchange is up to date). This result is desired and does not express a concern related the possibility of overlapping between the two items. To validate this outcome, the following section provides more investigation.

c. In your supply chain transaction applications are able to be communicated in real time (IT infrastructure construct) and information exchange is timely (SCV construct)

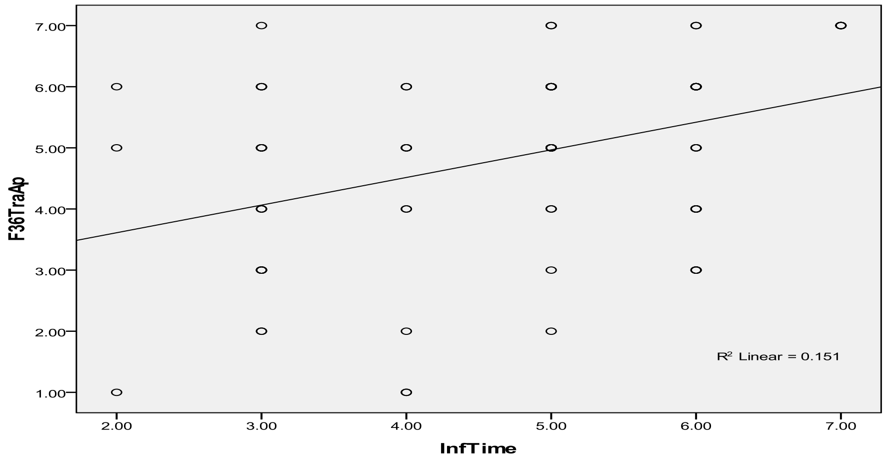


Figure 36: scatter diagram of the two investigated items (transaction applications & timely information)

As illustrated in figure 36, the R^2 value is almost 15% between the independent variable within IT infrastructure for SC integration construct (*in your supply chain transaction applications are able to be communicated in real time*) and the criterion variable within SCV construct (information exchange is timely). Thus, the predictor variable was able to explain 15% of the variance in the dependent variable. This percentage is quite limited to prove overlapping between the two items. To validate this conclusion, further examination is conducted in the following section.

d. In your supply chain transaction applications are able to be communicated in real time (IT infrastructure construct) and information exchange is up to date (SCV construct)

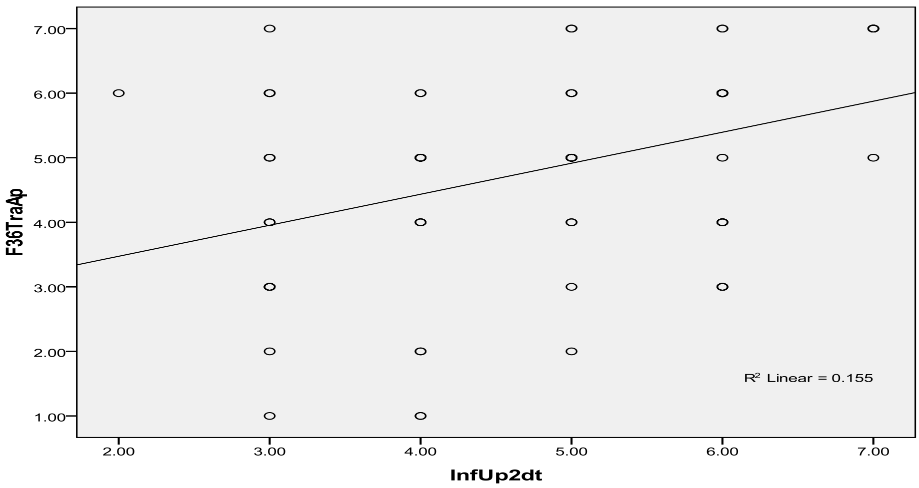


Figure 37: scatter diagram of the two investigated items (transaction applications & up to date information)

As depicted in figure 37, the R^2 value is almost 16%. This result indicates that the independent variable within IT infrastructure for SC integration construct (in your supply chain transaction applications are able to be communicated in real time) was able to explain 16% of the variance in the criterion variable affiliated with SCV construct (information exchange is up to date). This percentage is not big enough to raise any concern about the possibility of overlapping between the two items. Further examination is conducted to validate this result.

To sum up, the results of the linear regressions of the relationships between the investigated items within the IT infrastructure for SC integration as an independent variable and SCV as a dependent variable have illuminated that no concern should be raised about the possibility of overlapping between the two construct. The following section provides deeper examination using Chronbach's alpha analysis.

4. *To check the value of Chronbach's alpha if item deleted*

The construct under investigation is supply chain visibility as the dependent variable that incorporates some items suggested to overlap with other items within IT infrastructure for SC integration construct. This section provides the results of the Chronbach's alpha values after adding the suggested two overlapped items incorporating *in your supply chain planning and transaction applications are able to be communicated in real time.* More interest is in the value of Chronbach's alpha when these items are deleted from the construct.

a. In your supply chain planning applications are able to be communicated in real time (IT infrastructure construct)

Table 28: Reliability Statistics

Cronbach's Alpha	N of Items
.964	15

Table 29: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
In your supply chain.. ..planning applications are able to be communicated in real time	67.9000	257.813	.622	.965

As presented in figure 28, the value of Chronbach's alpha of SCV construct upon the inclusion of a new item (in your supply chain planning applications are able to be communicated in real time) that is originally part of IT infrastructure for SC integration construct is .964. This value proves high reliability of SCV construct. Table 29 illuminates that when the added item is removed from SCV construct the Chronbach's alpha value has jumped up to become .965. This result proves that the added item is not affiliated to SCV construct that in turn, validate other study findings that reached the same conclusion. Therefore, no further investigation is needed.

b. In your supply chain transaction applications are able to be communicated in real time (IT infrastructure construct)

Table 30: Reliability Statistics

Cronbach's Alpha	N of Items
.962	15

Table 31: Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
In your supply chain.. ..transaction applications are able to be communicated in real time	67.7468	259.217	.501	.965

Table 30 indicates the value of Chronbach's alpha (.962) for supply chain visibility construct upon the inclusion of the investigated item (in your supply chain transaction applications are able to be communicated in real time). Table 31 illustrates an increase in the value of Chronbach's alpha (.965) upon the deletion of the new item. This item is originally part of IT infrastructure for SC integration construct as an independent variable within the research model. This outcome reveals that this item diminishes the reliability of SCV construct. This finding validates other results that indicated no concern should be raised about the overlapping between IT infrastructure and SCV construct. Consequently, no more investigation is required.

To conclude, the concern raised about the possibility of overlapping between some items of the SCV construct and some items related to the IT infrastructure for SC integration construct has been examined using various statistical techniques. The findings of the analysis have not proven the potential overlapping between the two constructs. Consequently, no further investigation is required.

J. Typical copy of the employed survey

Improving supply chain visibility

Section A: Tracking System Capabilities

This section focuses on tracking your key product/s on returnable transport assets (RTAs) e.g. boxes, cages, trays, trolleys, pallets, cases.

1. What are the main characteristics of your core product?

- ☐ High-value
- ☐ Perishable
- ☐ Liquid
- ☐ Low-value
- ☐ Long-life
- ☐ Solid
- ☐ Fragile
- ☐ Sensitive
- ☐ Robust/durable
- ☐ Insensitive
- ☐ Other (please specify)

2. How do you manage your transport logistics activities?

- ○ Through our own transport fleet
- ○ Through our logistics service provider
- ○ Both
- ○ Other (please specify)

3. What is the main type/s of returnable transport assets (RTAs) used in carrying your products?

- ☐ Boxes
- ☐ Trolleys
- ☐ Trays
- ☐ Cases
- ☐ Cages
- ☐ Kegs
- ☐ Other (please specify)

4. Which system/s do you use in tracking your products and for how long have you used it?

	< 2 years	2-5 years	5+ years
Manual system	○	○	○
Barcodes	○	○	○
Passive radio frequency identification device (RFID)	○	○	○
Active radio frequency identification device (RFID)	○	○	○
Geographical positioning system (GPS)	○	○	○

Other (please specify) and for how long?

Improving supply chain visibility

5. Please indicate the extent to which you agree or disagree with the following statement:

Your tracking system for your core product helps you to…

	Strongly disagree						Strongly agree
..track RTAs on individual base across your supply chain	◯	◯	◯	◯	◯	◯	◯
..locate specific RTAs across your supply chain	◯	◯	◯	◯	◯	◯	◯
..identify current physical status of your RTAs	◯	◯	◯	◯	◯	◯	◯
..maintain historical information of RTAs used in your supply chain	◯	◯	◯	◯	◯	◯	◯
..reduce delivery time to your customer	◯	◯	◯	◯	◯	◯	◯
..reduce return time of empty RTAs	◯	◯	◯	◯	◯	◯	◯
..maintain continuous flow of products across your supply chain	◯	◯	◯	◯	◯	◯	◯
..reduce delivery errors to your customer	◯	◯	◯	◯	◯	◯	◯
..reduce return errors of empty RTAs	◯	◯	◯	◯	◯	◯	◯
..maintain quality of your products across supply chain operations	◯	◯	◯	◯	◯	◯	◯
..reduce waste associated with time and money	◯	◯	◯	◯	◯	◯	◯
..improve security aspects e.g. loss, counterfeiting and theft	◯	◯	◯	◯	◯	◯	◯
..reduce inefficient consumption of your resources	◯	◯	◯	◯	◯	◯	◯
..minimize errors in data capture	◯	◯	◯	◯	◯	◯	◯
..provide accurate information e.g. check out/in activities	◯	◯	◯	◯	◯	◯	◯
..provide updated information e.g. expected delays, route change	◯	◯	◯	◯	◯	◯	◯

6. How do you evaluate your satisfaction level with your tracking system?

	Extremely dissatisfied						Extremely satisfied
We are	◯	◯	◯	◯	◯	◯	◯

Section B: Relationship with Logistics Service Provider

In this section, please focus on your major logistics service provider specifically the one who provides your transport logistics service. (Please skip this section if you do not deal with a logistics service provider)

1. Your key logistics service provider....

	Strongly disagree						Strongly agree
..has customised tools and machinery to your needs	◯	◯	◯	◯	◯	◯	◯
..has dedicated significant investment and capacity to your relationship	◯	◯	◯	◯	◯	◯	◯
..has knowledge about you that is difficult to replace	◯	◯	◯	◯	◯	◯	◯
..is involved in developing your logistics processes	◯	◯	◯	◯	◯	◯	◯
..is involved in quality and improvement initiatives	◯	◯	◯	◯	◯	◯	◯
..helps you to learn about new technologies and markets	◯	◯	◯	◯	◯	◯	◯

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2. You and your key loistics service provider....

	Strongly disagree						Strongly agree
...Manage your relationship based on trust which is more significant than a formal contract	○	○	○	○	○	○	○
..have created formal and informal arrangements for information exchange	○	○	○	○	○	○	○
..have planned to anticipate and resolve operative problems	○	○	○	○	○	○	○
..have developed ways to improve cost efficiencies	○	○	○	○	○	○	○
..have a dedicated team for your Continuous Replenishment Program (CRP) or other Efficient Consumer Response (ECR) practices	○	○	○	○	○	○	○
..share best practices	○	○	○	○	○	○	○
..have a long-term relationship	○	○	○	○	○	○	○
..have jointly established goals	○	○	○	○	○	○	○
..do not take any intentional actions that can hurt your relationship	○	○	○	○	○	○	○

Section C: Your IT Infrastructure

This section focuses on your firm’s IT infrastructure for managing supply chain and logistics activities.

1. Your IT infrastructure....

	Strongly disagree						Strongly agree
..supports the use of automatic data capture systems across your supply chain	○	○	○	○	○	○	○
..allows common definitions of key data elements across your supply chain	○	○	○	○	○	○	○
..offers consistency in storing the same data in different databases across your supply chain	○	○	○	○	○	○	○

2. In your supply chain,....

	Strongly disagree						Strongly agree
..planning applications are able to be communicated in real time	○	○	○	○	○	○	○
..transaction applications are able to be communicated in real time	○	○	○	○	○	○	○
..customer relationship applications are able to be communicated with internal applications of your firm	○	○	○	○	○	○	○

3. Your supply chain applications

	Strongly disagree						Strongly agree
..are able to be communicated with internal applications of your firm	○	○	○	○	○	○	○

Section D: Your Firm’s Integration

This section focuses on your firm’s internal and external integration practices.

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1. Within your firm,....

	Strongly disagree						Strongly agree
..all departments are connected by a single central information system	○	○	○	○	○	○	○
..cross functional teams to solve problems are used	○	○	○	○	○	○	○
..communications from one department to another are expected to be routed through ‘‘proper channels’’	○	○	○	○	○	○	○
..internal management communicates frequently about goals and priorities	○	○	○	○	○	○	○
..openness and teamwork are not encouraged	○	○	○	○	○	○	○
..when problems occur, finding someone to blame is more important than finding a solution	○	○	○	○	○	○	○
..formal meetings are routinely scheduled among various departments	○	○	○	○	○	○	○
..when problems or opportunities arise, informal, face-to-face meetings never occur	○	○	○	○	○	○	○

2. Across your supply chain,....

	Strongly disagree						Strongly agree
..accounts receivable processes are automatically triggered when you ship to your customers	○	○	○	○	○	○	○
..accounts payable processes are automatically triggered when you receive supplies from your suppliers	○	○	○	○	○	○	○
..inventory holding is minimised	○	○	○	○	○	○	○
..supply chain-wide inventory is jointly managed with your suppliers and your logistics partners	○	○	○	○	○	○	○
..suppliers and logistics partners deliver products and material just in time	○	○	○	○	○	○	○
..distribution networks are configured to minimise total supply chain-wide inventory costs	○	○	○	○	○	○	○
..production and delivery schedules are shared	○	○	○	○	○	○	○
..performance metrics are shared	○	○	○	○	○	○	○
..supply chain members collaborate in arriving at demand forecasts	○	○	○	○	○	○	○
..downstream partners share their actual sales data with you	○	○	○	○	○	○	○
..customers give you feedback on quality and delivery performance	○	○	○	○	○	○	○
..demand levels are visible	○	○	○	○	○	○	○
..inventory data are visible at all stages	○	○	○	○	○	○	○

Section E: Your Supply Chain Visibility

This section focuses on the level of information sharing between your firm and your supply chain trading partners.

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1. Your supply chain trading partners....

	Strongly disagree						Strongly agree
..are informed in advance about changing needs	◯	◯	◯	◯	◯	◯	◯
..share proprietary information with you	◯	◯	◯	◯	◯	◯	◯
..keep you fully informed about issues affecting your business	◯	◯	◯	◯	◯	◯	◯
..share business knowledge of core business processes with you	◯	◯	◯	◯	◯	◯	◯
..and you exchange information that helps establishment of business planning	◯	◯	◯	◯	◯	◯	◯
..and you inform each other about changes that may affect the other partners	◯	◯	◯	◯	◯	◯	◯

2. Information exchange between your supply chain trading partners and you is...

	Strongly disagree						Strongly agree
..timely	◯	◯	◯	◯	◯	◯	◯
..up to date	◯	◯	◯	◯	◯	◯	◯
..generated frequently	◯	◯	◯	◯	◯	◯	◯
..accurate	◯	◯	◯	◯	◯	◯	◯
..valuable and applicable to specific tasks	◯	◯	◯	◯	◯	◯	◯
..consistently presented	◯	◯	◯	◯	◯	◯	◯
..easy to understand	◯	◯	◯	◯	◯	◯	◯
..interpretable	◯	◯	◯	◯	◯	◯	◯

Section F: Your firm’s Performance

This section focuses on your firm’s performance compared to your competitors.

1. You are able to....

	Strongly disagree						Strongly agree
..shorten your product delivery cycle time	◯	◯	◯	◯	◯	◯	◯
..offer timeliness of your after sales service	◯	◯	◯	◯	◯	◯	◯
..improve your productivity level	◯	◯	◯	◯	◯	◯	◯
..keep a strong and continuous bond with your customers	◯	◯	◯	◯	◯	◯	◯
..have precise knowledge of your customer buying patterns	◯	◯	◯	◯	◯	◯	◯
..increase sales of your existing products	◯	◯	◯	◯	◯	◯	◯
..find new revenue streams e.g. new products, new market	◯	◯	◯	◯	◯	◯	◯

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2. You are able to…

	Strongly disagree						Strongly agree
..offer competitive prices							
..offer prices as low as or lower than your competitors							
..compete based on quality							
..offer products that are highly reliable							
..offer products that are very durable							
..offer high quality products to your customer							
..deliver customer orders on time							
..provide dependable delivery							
..alter your product offerings to meet client needs							
..respond well to customer demand for "new" features							
..deliver product to market quickly							
..be first in the market in introducing new products							
..lower time-to-market than industry average							
..have fast product development							

3. Compared to your major competitors, your……

	Significantly lower						Significantly higher
..return on total assets in 2007 were							
..return on total assets in 2008 were							
..return on total assets in 2009 were							
..return on sales in 2007 were							
..return on sales in 2008 were							
..return on sales in 2009 were							

Section G: Background Information

1. What is the type of industry your firm is affiliated with?

2. What are the core products provided by your firm?

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3. What is your job-title within the organization?

4. How many years have you held this position?

5. Please indicate the period (in years) you have been working in this organization:

6. Please indicate the total number of employees in your organization:

7. Please indicate the average annual sales revenue in millions of $/£/€:

Section H: Final notes

§ Thank you for completing this survey and be assured that all information is strictly confidential.

§ If you have any inquiry, please do not hesitate to contact us.

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1. If you are interested in a summary report of the research, please provide the following details

Name (optional)

Email address