Chapter 1   INTRODUCTION

1.1 Introduction

This research investigates the adoption by organizations of lean principles for creating business values in the end-to-end supply chain context, in response to the increasingly complex operations as a result of globalization leading to rising costs, and deteriorating efficiency. Thus, firms' supply chain position as the contextual factor of adoption is incorporated into the research design. Two prominent lean approaches, i.e. lean manufacturing and lean services, are evaluated, using both quantitative and qualitative methods for answering different research questions. First, the research explains lean adoption in upstream supply chains by establishing the relationships of lean manufacturing with supply chain integration (SCI) and supplier integration as a specific context of SCI, at process level, based on the empirical data obtained from 558 companies in 17 countries. Second, the research explains lean adoption in services that focus on user experiences at the customer touch points in downstream supply chains, complementing the findings obtained in the previous stage. Two case studies are conducted, aiming to provide the insights of lean service enabling technology application at the user level in both individual and organizational aspects. The research contributes to these two levels of understanding of lean adoption through comparing and contrasting them in two different supply chain directions, so that continuous improvement to supply chain members can be supported by adopting lean principles.

1.2 Research questions

With the globalization of business comes increased cross-border activity and new investment in overseas economies, which brings not only new opportunities, both for the firms investing and the economies in which they invest, but also additional costs, particularly in terms of the logistics of multiple sourcing for multi-product enterprises. Becoming a lean enterprise that emphasizes simplification and elimination of wasteful processes, enables global manufacturers to streamline their supply chain through improving throughput, reducing costs, and delivering shipment with shorter lead times (King, 2009; Oliver *et al.*, 1993; Ryan, 2001). Littlefield and Shah (2009) researched 320 enterprises across different vertical industries in the US regarding their lean manufacturing

processes, and the results showed that lean enterprises are able to achieve 98% on-time-delivery of products and 5% inventory costs as a share of revenue, compared to the industry average of 64% and 7% respectively. On the other hand, according to a longitudinal study of the European manufacturing industry, Bhasin and Burcher (2006) reported that lean manufacturing can help reduce waste by 40%, cut costs by between 15% and 70%, reduce space and inventory requirements by 60%, push productivity up between 15% and 40%, whilst cutting process changeovers by 60%. Both studies show the tremendous benefits and usefulness of using lean principles in manufacturing. Undoubtedly, lean manufacturing creates business values in operational improvements on lead-time reduction and cost savings as a result of waste reduction objectives. Besides, as the literature review in Chapter 2 will show, lean principles also deliver operational improvements at the customer touch points of service and retail firms based on business rules.

However, there has been no literature studying how values are influenced by the management competences of manufacturing firms that include technology, people and systems, in the end-to-end supply chain aspect, at both process and customer levels. The thesis endeavours to partly remedy this omission. It consists of four research publications. The first two articles study the causal relationship between lean manufacturing adoption and organizational process integration in the form of SCI and supplier integration, while the last two articles explore the user experience of using radio frequency identification (RFID), a lean services enabling technology, with the aim of providing insights into the technical aspect of adopting lean services to organizations in creating customer value.

The first publication, "An extension of IDT in examining the relationship between electronic-enabled supply chain integration and the adoption of lean production", authored by S. So and H. Sun, published online in *International Journal of Production Research* (1st February, 2010), analyses the adoption of lean principles in global manufacturing firms. Based on the survey data obtained from 558 firms in 17 countries, it studies the relationship between lean manufacturing adoption and electronically-enabled SCI which takes part in both internal and external supply chains. The study addresses the following four research questions:

1. **What are the factors causing manufacturers to accept lean manufacturing?**

2. **How significant is the value of lean manufacturing perceived by**

manufacturers?

3. **What impact does SCI have on the adoption of lean manufacturing?**

4. **What are the aspects of SCI that influence the adoption of lean manufacturing?**

The second publication, "Adopting lean principle as sustainable manufacturing strategy in an electronic-enabled supply chain environment", authored by S. So, published in *International Journal of Sustainable Economy* (Vol. 2, No. 3, 2010), essentially an extension of the first article, further examines the effect of supplier integration, an external SCI focusing on information management and supply policies, on lean manufacturing adoption, based on the same empirical data set used in the previous study. It addresses the following research questions:

1. **Is adopting lean manufacturing in regular operations the sufficient condition for becoming sustainable practice?**

2. **What impact does collaborative information management for supplier integration have on the adoption of lean manufacturing?**

3. **What impact do supply policies have on the adoption of lean manufacturing?**

The third publication, "Creating ambient intelligent space in downstream apparel supply chain with radio frequency identification technology from lean services perspective", authored by S. So and H. Sun, published in *International Journal of Services Science* (Vol. 3, No. 2-3, 2010), is a case study that examines adopting RFID technology in the operations of an apparel retailer through exploring the experiences of using and implementing a new service. It aims to answer the following research questions:

1. **What are the adoption factors that cause the retailer to accept RFID?**

2. **What are the improvements that RFID brings to the retailer's operations?**

3. **What are the issues of implementing RFID in the retailer's operations?**

The fourth publication, "Learning from failure: a case study of adopting radio frequency identification technology in library services", authored by S. So and J. Liu, published in *International Journal of Technology Intelligence and Planning,* (Vol. 3, No. 1, 2007), is a further case study that explores the circumstances of implementing RFID in library

operations, with the focus on understanding implementation issues and how they can be resolved, as well as drawing conclusions and practical implications as industry insights. The following research questions are addressed:

1. **What are the issues of implementing RFID technology in lean service operations?**

2. **What are the solutions to the issues of implementing RFID technology in lean service operations?**

3. **What are the practical implications of using RFID technology to improve customer services and streamline operations?**

The next section will provide an outline of the thesis. It describes the approach that has been taken in the structuring of the various chapters in the thesis.

1.3   Outline of the thesis

Chapter 1 provides a summary of the background to the research and highlights the main research questions. It introduces the structure of the thesis, organized around four separate but related publications. Chapter 2 reviews the relevant academic literature. It reviews the lean principles related literature with a special focus on the adoption in e-supply chains. Also, related literature on research methodology for evaluating the reliability, validity and generalizability of the empirical data gathered from the studies of this thesis is addressed.

Chapters 3, 4, 5 and 6 consist of individual but related refereed articles that have been published in paper or online form. The first article (Chapter 3) was published online and the publication schedule of the paper form is still not available. The research conducted by the first author, i.e. the researcher, who is the sole investigator of this study, was fully funded by a research grant at City University of Hong Kong, managed by the co-author. The first author is the only research staff recruited with this funding. The paper studies the relationship between electronic-enabled SCI in both internal and external scenarios, and lean manufacturing adoption. The leanness is measured by the extent of supply strategy restructuring, the streamlined process, pull production implementation, and workforce empowerment supporting the lean manufacturing initiative.

The second article (Chapter 4) is an extension of the first publication and studies the casual relationship between lean supply strategy towards supplier integration and the adoption of

lean principles in manufacturing, based on the same empirical data set used in the first publication. The lean supply strategy is measured by suppliers' capability of supporting lean manufacturing through: (a) information flow integration in supply management that improves manufacturers' workforce, (b) delivery and historical performance and ability to share sensitive business information to enhance product innovation and operations of manufacturers.

The third article (Chapter 5), as with the first article, the first author was the sole investigator of the study. The project was financially supported by City University of Hong Kong with the budget approved by the co-author. It studies a successful case of adopting lean services enabling technology to apparel retailing. The role of lean services in the downstream supply chains and how lean services can be realized in retailing by RFID technology are discussed. Triangulation that involved the convergence of multiple data sources was used to improve the validity of the study (Yin, 2009). Qualitative data was then collected by interviews and observations from both management and first line staff of the retailer, and the representatives from its RFID technological partner, which is essentially a different company with business of a different nature. The data was analyzed using a qualitative content analysis technique (Carson *et al*., 2001; Graneheim and Lundman, 2004) by extracting the underlying attributes of user perceptions and experiences on using RFID in order to obtain more realistic adoption factors based on real world experiences.

The research for the fourth article (Chapter 6) was financially supported by a research grant at The Hong Kong Polytechnic University with the budget approved by the co-author, who was the Head of Department in which the researcher worked. The first author is the only researcher in the project. It studies a failure case of adopting lean services enabling technology for library operations by exploring the application of RFID technology in library services that serves two purposes: (a) automating and streamlining library operations, and (b) providing intelligent services to enhance customer values. Qualitative data was obtained from different sources, including library staff and the professional consultant, and an independent party, who made recommendations to the library. The practical implications of this case study can serve as the reference to other organizational improvement programmes. Last but not least, the conclusion of the thesis is detailed in Chapter 7, the final chapter of this thesis.

In summary, the thesis contributes to the understanding of various influential factors

against the adoption of lean principles in manufacturing and services by considering the firms' supply chain position. At the process level, the first two studies revealed that SCI and supplier integration, as a form of process integration, have significant positive influence on the adoption of lean manufacturing in electronically-enabled supply chains. The last two studies analyzed the practical considerations of adopting lean services enabling technology at the user level, in both individual and organizational aspects, with a focus on user perceptions and experiences. The case studies revealed that adopting lean principles in user-centric services was influenced by individual factors which were characterized by user experience and organizational factors that emphasize consistency with existing values, past experiences and needs of the adopters. The results complement the findings of the first two studies in understanding the adoption of lean principles along the two different supply chain directions. Hence, value can be specified more suitably to business and customers based on these two level of understandings of lean adoption, while continuous improvement to supply chain members can be established through linking the value stream from the upstream to downstream supply chain as a consequence of adopting lean principles.

Chapter 2   LITERATURE REVIEW AND METHODOLOGY

2.1   Introduction

The highly competitive marketplace forces manufacturers moving their production lines to locations outside their home countries where there are lower labour costs. The change triggers a radical transformation in manufacturing supply chains that may include operational processes, buyer and supplier relationship, workmanship, and customer values. A new method is needed for not only manufacturers but also their trading partners to cope with the changes. Lean thinking, which started in manufacturing for waste reduction, involves a collection of management principles leading to substantial improvement in productivity and resource usage, including Just-in-time (JIT), the pull production system, supply management, standardization of manufacturing processes, cellular manufacturing, lot-size reduction, and workforce empowerment (Bayou and Korvin, 2008; Creese, 2000; Hines, 1996; Pérez and Sánchez, 2000; Wu, 2003; Taj, 2008; Wang, 2008). Lean principles are widely used in manufacturing supply chains that bring significant operational improvements to supply chain stakeholders, and the benefits have been extended to non-manufacturing in downstream supply chains (Aikens, 2011; Bozarth *et al.*, 2009; George and Wilson, 2004; Jayaram *et al.*, 2008; Krishnamurthy and Yauch, 2007, Sehgal, 2009).

As indicated previously, the thesis, based on four research journal papers, explores the antecedents and implementation issues of adopting lean principles and underlying technology in organizations seeking to create business values in the supply chain context. Specifically, the relationships of lean principles, as an organizational management system, with key supply chain activities, including managing suppliers and production in upstream supply chains (lean manufacturing) and managing store operation and customer services in downstream supply chains (lean services), are explored and analyzed. The studies seek to better understand how firms in respective supply chain positions adopt lean principles that create business values. The adoptions of lean in these two dimensions are compared and contrasted so that a common adoption approach is summarized.

The literature review has three main sections, aiming to critically review the relevant literature and establish the gaps of contemporary knowledge that clearly establish the

originality of the study and provide the foundation for the four articles that follow this chapter. The first section reviews the lean principles literature in relation to supply chain management (SCM) and value creation. The second section reviews the literature on the adoption of lean principles in organizations and identifies a gap in this extensive body of research: there have been no previous studies that have addressed adopting lean principles for creating value corresponding to firms' supply chain position and identifying the circumstances and antecedents that influence the adoption in both individual and organizational aspects. The final section reviews the methodology literature that is relevant to the studies and helps establish the reliability and validity of the collected empirical evidences, as well as the generalizability of the research models.

2.2   Lean principles from a supply chain perspective

2.2.1   Creating value with lean principles

Lean principles began in manufacturing, originating in Toyota, as reflected in names such as 'Toyota production system (TPS)' or 'Just-in-time (JIT) manufacturing' beginning back in the 1960s, aiming for a total management system that works for any type of business (Bruun and Mefford, 2004; Ohno, 1998; Reichhart and Holweg, 2007; Taj, 2008; Wu, 2003). Being one of the manufacturing best practices, lean principles preach simplification and elimination of wasteful tasks, which is applicable to overly complex and nonintegrated processes that are inefficient and provide little added *value* (Bayou and Korvin, 2008). Adopting lean principles as a total management system is a strategic move and the success is determined by how well a company coordinates all of its internal processes, including operations with its suppliers and customers, to products and services that offer *value* (Russell and Taylor, 2009). According to Harrison and Hoek (2008), *value* is relative advantage specified as perceived benefits obtained from products/services from the customer perspective, while from the management perspective it is perceived as *economic profitability*. It can be extended to other supply chain stakeholders as a *value stream* in which the *value-adding processes* begin as raw materials from suppliers that are progressively converted into finished product bought by end-customers, such as aluminum is converted into one of the constituents of a can of coke. Rogers (1983) and Moore and Benbasat (1991) argued that relative advantage is a major factor affecting innovation adoption by end-users in which *perceived benefits (PB)* and *perceived usefulness (PU)* can be used as the measurements for the new idea. A major *value* of applying lean principles in

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manufacturing is reducing customer order fulfillment time by eliminating non-value-added waste from the processes (Ohno, 1988), and value objectives such as reducing lead-time or inventory can be applied to services by streamlining processes so that businesses can be more responsive to changes (George and Wilson, 2004; Russell and Taylor, 2009).

Ohno (1988) identified seven kinds of waste that need to be eliminated in manufacturing, and they are: (1) overproduction, (2) transportation, (3) inventory, (4) motion, (5) defects, (6) over-processing, and (7) waiting. These seven wastes represent the most commonly wasted resources and their associated wasteful manufacturing activities which do not add value or are unproductive: e.g. mistakes which require rectification, production of items no one wants, so that inventories and remaindered goods pile up, processing steps which are not needed, movement of employees and transport of goods from one place to another without any purpose, groups of people in a downstream activity waiting because an upstream activity has not delivered on time, and goods and services that do not meet customer needs (Womack and Jones, 2003). The last activity, not meeting customer needs, is the eighth waste introduced by Womack and Jones (2003) as the key factor considered by a lean enterprise. The pull production approach and the *kanban* control system are at the heart of this effort in communicating the downstream demand to suppliers through manufacturers (Bruun and Mefford, 2004; Martin, 2010; Taj, 2008; Wu, 2003). These wastes can be classified into two categories: i.e. waste in the form of *resources* (raw materials, WIP, etc.) that are transformed in manufacturing, and *transforming resources* such as people, processes, and facilities (Lewis, 2006). Each of these wastes corresponds to some form of *loss in value* such as loss in material, factory, and equipment utilization, time, man-hours, and dollars, representing costs that companies must ultimately pass on to their customers, something which should be avoided (Ruffa, 2008).

Lean principles help analyze businesses systematically to establish the baseline of *value-adding processes* and to identify the incidence of wastes mentioned earlier, aiming to get parts and data to flow through business processes more efficiently. The more detailed analysis, prompted by these wastes, encourages a greater understanding of processes and their relationships obtained through *supply chain mapping*, an end-to-end process analysis to evaluate product flow through visualizing and tracking activities starting from suppliers, manufacturers to customers (Gartner and Cooper, 2003; Harrison and Hoek, 2008; Swank, 2003). End-to-end integration of supply chain processes enables *kanban*, or pull signals, communicating actual demand and usage to initiate the flow of materials. Establishing a

kanban linked-supply chain in a pull production environment helps manufacturers maintain low stock levels while, simultaneously, improving the capability to deliver and capture customer value to determine how well they are supplying their customer base (Black, 2007; Martin, 2010; Taj, 2008; Wu 2003). Retailers may use such processes to increase value, or look at the prices of their products in order to price them competitively (Martin, 2010). Hence, meeting the intended purpose of adopting lean principles for value creation could be influenced by factors related to both upstream and downstream, and it is crucial to identify these factors to support strategic decision-making concerning adopting and implementing lean.

2.2.2 The integrated supply chain and influences leading to lean adoption

In adopting lean principles as business practice to create values through streamlining operations and eliminating wasteful tasks, organizations need to implement relevant information systems, technologies or production strategies involving organizational changes, which pose the potential of significant impacts on various aspects of a firm's operations (Womack and Jones, 2003). These impacts could range from internal impacts on different business units to external impacts relating to trading partners involving supply policies, manufacturing processes, and inventory control, that characterize the major upstream supply chain activities, as well as item management and store operations, which, on the other hand, characterize the major activities in downstream supply chains (Bozarth and Handfield, 2008; Chen and Paulraj, 2004; Heizer and Render, 2007; Russell and Taylor, 2009). Therefore, using lean principles concerns not only internal manufacturing processes, but also operations of the entire supply chain (Oliver *et al.*, 1993). Extending lean principles from manufacturing to SCM can further leverage the supply chain's performance to be more responsive to demand change and to have lower costs (Oliver *et al.*, 1993; Ryan, 2001).

A supply chain comprises multiple participants and each of them involves a number of operational and managerial activities where a manufacturer sits in the middle controlling the flow of material and information through its internal supply chain and reaching out to its suppliers and customers via an external supply chain (Christopher, 1998; Li, 2007). **Figure 2.1** illustrates an integrated supply chain with the three major players: i.e. suppliers, manufacturers and customers and corresponding value-adding activities from purchasing and flow-control of materials in the upstream, among suppliers and manufacturers, to

customer services and sales management in the downstream, among manufacturers and customers.

Christopher (1998) emphasized that leading-edge companies seek to make supply chains more competitive as a whole, through adding values and cost reduction by integrating the internal business functions of the companies, including purchasing, material management and inventory control. This, however, is essentially insufficient and the integration must be extended to their trading partners, for example, upstream suppliers, in order to achieve true supply chain integration (SCI). Also, Bhasin and Burcher (2006) argued that manufacturers' growing profits through cost cutting is not likely to be sustainable and must be balanced with sales growth, innovation, new product development and process improvement, where lean manufacturing plays an important role in achieving this goal through supplier collaboration. Integrating with suppliers with lean principles offers manufacturers the benefits of reduced business risks through joint R&D or joint investment in technology, decreased inventories by sharing sales forecasts or production schedules, improved product quality and knowledge by co-designing products, and can lead to more stable supply prices by committing to long-term partnerships (Hines, 1996).
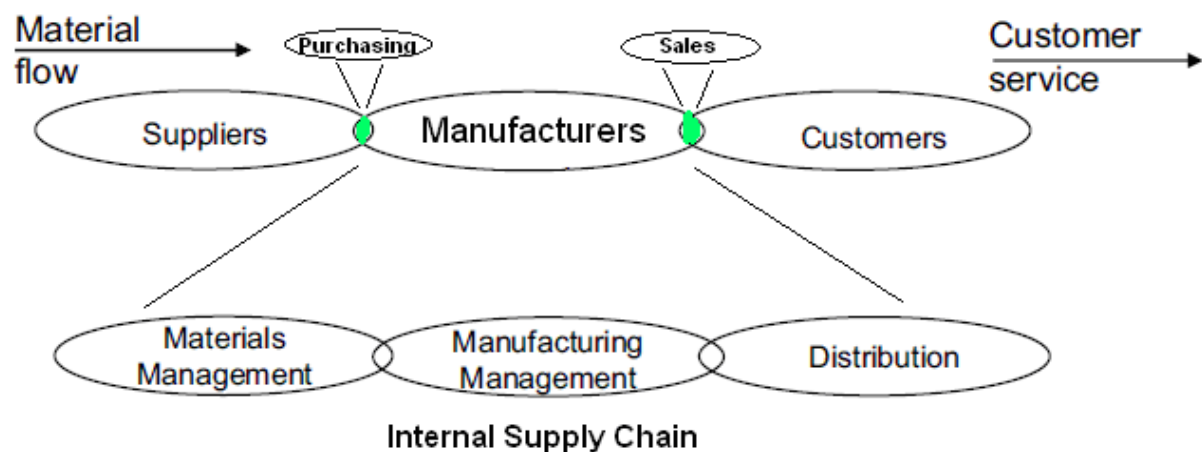

Figure 2.1 An integrated supply chain (adapted from Christopher, 1998)

Mitigating business risks derived from supply chain overall variability can be achieved through supplier integration by buffering inventory at various strategic locations of the supply chain where the decoupling point locations can be shifted toward upstream

suppliers according to different product models (O'Brien and Azambuja, 2009). For example, the engineering-to-order (ETO) model demands suppliers hold more strategic stocks than other models for product customization that shifts risks from manufacturers to suppliers, leading to upstream supply chains characterized with *long-term contractual relationship*, *high-level of information sharing*, and a *high-level of relation-specific investments* (George and Wilson, 2004; O'Brien and Azambuja, 2009). Eventually, it also offers the benefits of lead-time reduction, standardization of products and processes, and information transparency, to various supply chain members (Tommelein *et al.*, 2009).

The Internet, a platform-independent communications highway, can be used as a cross-company interface to offer information transparency through business-to-business (B2B) e-trading systems by fostering operationally efficient, connected and cooperative relationships among manufacturers, suppliers and distributors (Neef, 2001). The most typical B2B feature is the formation of online trading communities and electronic marketplaces. For example, Global Sources, a global B2B media company, creates an online trading community of over 888,000 active buyers and more than 253,000 suppliers in over 240 countries, in which Wal-mart, Best Buy, Samsung and Carrefour, are among the buyers making use of the company's electronic marketplaces (Global Sources, 2009; 2010) that are able to cope with their sourcing strategies and help communicate their trade effectively (Datamonitor, 2009; Global Sources, 2010). Such structures have been enabled by the Internet and seek to offer cost reductions in procurement and also in the processing of such transactions that enable trading partners to integrate electronically on the supply chain information systems along the 'e-supply chain' (Harrison and Hoek, 2008).

2.2.3 EMSC and integrated supply chain

Having conducted a global study on lean operation with 12 first-tier autocomponent suppliers, Ryan (2001) argues that employing Internet-enabled supply chain information systems might be an effective lean approach to reduce the increasing costs of the ever complex supply chain and enhance buyer-supplier relationships in the long run, through managing communication and information on a real-time basis. The capability of managing various supply chain activities in a timely and cost effective manner, with Internet technology, becomes increasingly important to manufacturers in order to stay competitive in their markets, in which EMSC are promising achievement of this objective. EMSC are manufacturing supply chains in an e-Business environment comprising *internal*

supply chains which includes various production management and support functions, and an *upstream supply network* as part of the external supply chain (Christopher, 1998; Li, 2007). This offers the environment the potential to achieve lean improvement objectives through facilitating information exchange among various supply chain members who associate with various influential factors affecting the adoption of lean production or supplier integration by manufacturers.

Manufacturers realized some time ago that operating in an integrated supply chain environment is a key capability to better support decision-making, planning and transaction processing by using information systems or supply chain technologies, for example, electronic-data Interchange (EDI), enterprise resources planning (ERP) systems, B2B and Internet/Extranet (Hugos, 2003), constituting the EMSC infrastructure (Bruun and Mefford, 2004; Li, 2007; Pérez & Sánchez, 2000). Other key capabilities to improve operation efficiency, cost effectiveness and waste reduction involve adopting new production strategies, for example, lean manufacturing (Creese, 2000; Wang, 2008; Womack *et. al.*, 1991).

Lewis (2006) emphasized that lean manufacturing can reduce the level of input resources in the system for a given level of output, i.e. achieving higher efficiency, by eliminating wastes from the system through adopting *relevant supply strategy* and can give manufacturers sustainable competitive advantage. As supply management is highly related to demand driven (pull) supply chains through better coordinating material flow, inventory and production planning, implementing appropriate EMSC-enabled supplier integration strategy could influence the long-term adoption of lean manufacturing. Lean manufacturers could further integrate with upstream suppliers over the EMSC with speedy data communication and reliable information management that may influence the continuous development and long-term adoption of lean manufacturing ultimately (Li, 2007; Rudberg and Olhager, 2003; Ryan, 2001). With the emergence of information technology (IT), manufacturers migrate to e-kanban, an electronic version of *kanban* control system, on existing ERP platforms with improved scalability so that it is easier to apply the replenishment methodology to more and more suppliers by connecting to EDI and the internet (Bozarth and Handfield, 2008; Waters, 2009). Integrating kanban and ERP offers the benefit of combining the planning capabilities of ERP with the control capabilities of kanban that creates and maintains more accurate information for lean manufacturers in the EMSC (Bozarth and Handfield, 2008). With the burgeoning use of

EMSC-enabled SCI, lean manufacturers can hence more tightly integrate with their supply chain counterparts where this helps companies to not only share the values of lean practices but also to establish a closer relationship in the long run.

The preceding sub-sections introduced lean principles as a management philosophy that creates business value aimed at waste reduction in both manufacturing and non-manufacturing firms. EMSC-enabled SCI, representing both intraorganizational and interorganizational integrations by electronic mean, may have a significant effect on its adoption by organizations as connected enterprises in the supply chains. The next section will discuss the circumstances of adopting lean principles to organizations in the form of lean manufacturing and lean services for value creation in supply chains.

2.3   Value creation in supply chain by adopting lean principles

Based on the value chain model (Porter, 1985), George and Wilson (2004) argued that the value chain of each firm extends from suppliers all the way to customer satisfaction, is in which the *value* reaches beyond the four walls of the company, deep into the supply chain as a consequence. Porter (1985) identified the strategic activities in an enterprise that increase business value if they were linked appropriately. Christopher (1998) extended this firm-based value chain concept to supply chains in which procurement and manufacturing characterize the activities in the upstream supply chains, while customer services represent the major activities in the downstream supply chains. Although lean principles has shown its strength as a total management system in creating *value* by adapting to today's era of global supply chains and information systems (Ohno, 1988), understanding management's decision processes and individual users' attitudes to accepting lean principles helps formulate relevant adoption tactics from the supply chain perspective. Behavioral theories, in particular, the diffusion/adoption of innovations (Rogers, 1983; 1995), provide a theoretical basis for modeling *lean manufacturing* based on a systematic decision process, which help study lean adoption in the upstream supply chains in terms of improving business values. On the other hand, exploring the end-users' attitudes of using *lean services* at the customer touch points helps evaluate lean adoption in the downstream supply chains reflecting the improvement of customer values.

2.3.1   Lean manufacturing adoption

Ohno (1988) argued that the most important objective of lean manufacturing is to increase

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production efficiency by consistently and thoroughly eliminating waste which is supported by *JIT*, aiming at pulling the right goods needed, in the right amount and at the right time, by using *kanban* to communicate the information between each of the processes to control the amount of production, and ***automating the processes with intelligence*** through incorporating human touch, for example, individual skill and teamwork, into the production systems so that machines are equipped with foolproofing systems to prevent defective products. In order to systematically adopt JIT in manufacturing, Buker (1991) established structural JIT implementation approach based on three management capabilities to systematically adopt lean manufacturing that eliminates Ohno's seven wastes: ***technology management*** concerning the implementation of a responsive production system to improve existing processes through streamlining, reorganizing or restructuring the layout and set-up, e.g., using cellular layout, so that waste can be reduced and response time can be minimized, ***people management*** focusing on the development of human capital to support the continuous improvement objective in JIT by creating a proper working environment for employees from the president to the hourly workers through empowering and training of the workforce, and ***systems management*** aiming to address the effective distribution of parts and materials as well as proper use of limited enterprise resources which include restructuring supply strategy by forming a partnership with suppliers and establishing pull production systems so that parts and materials can be produced on demand with very short lead times. The benefits of these changes cannot be observed only if they are put into practice and used regularly for the long term, which consequently requires a systematic adoption strategy.

However, adopting lean manufacturing, just like adopting other innovative ideas or practices could bring significant impact on and enormous changes to operations, even when it has obvious advantages, and is often difficult due to a lengthy implementation period and the possibility of failure in the process of adoption. On the basis of over four thousand studies of adoption of innovation across diverse populations and cultures around the world, Rogers (1995) developed an innovation decision process (IDP) for an organization and its management shaping their innovation adoption strategies by facilitating change management. The process consists of a series of activities, through which an organization evaluates an idea and decides whether or not to incorporate the innovation into practice, that helps create conditions for change. Rogers (1995) emphasized that the decision of accepting innovations can be influenced by many factors,

such as *perceived values*, that lead to a different hierarchy of innovation effects. In order to support various supply chain members in making appropriate decisions throughout their entire decision process, Rogers' IDP identifies five decision factors in an organizational change process, which can be used to frame the adoption strategy with management interventions at suitable time throughout the process, that involves: ***knowledge*** (understanding of innovations), ***persuasion*** (exploring perceived attributes that lead to accept innovations), ***decision*** (adopt/reject innovations), ***implementation*** (involving operational and organizational issues that will be faced when putting a new idea to use), and ***confirmation*** (occurs when decision-makers recognize the benefits of innovations and integrate them as ongoing practice, i.e. ***adoption***). Based on the work of Rogers (1995), the on-going adoption of lean manufacturing as sustainable strategy is a long term commitment coming up through a structural decision process which involves the recognition of operational competencies, implementation issues, and the benefits of integrating lean into the value-adding activities in the supply chain around the manufacturers.

Nevertheless, adopting lean manufacturing in an e-supply chain requires substantial procedural and operational changes in light of the reengineering of key business processes that typically impacts the organizational structures, policies and employees of the company and its trading partners (Bergström and Stehn, 2005; Panta *et al.*, 2003; Yasin *et al.*, 2003). Use of an approach such as Rogers' IDP (1995) will help establish a systematic organizational change process, in which its effectiveness is mainly influenced by the extent of supplier integration and the level of information sharing (Fang *et al.*, 2008). The next sub-section will discuss the influence of supplier integration and its associated relationship activities on lean manufacturing adoption.

2.3.2 Supplier integration effect on lean manufacturing adoption

Matopoulos *et al.* (2009) revealed that only 10% of supply chains are regarded as fully integrated based on a SCI study in the European automotive industry by Towill *et al.* (2000). A more recent survey, by Poirier and Quinn (2003), similarly concluded that only 10% of the supply chains in the US had achieved external integration. On this basis, Matopoulos *et al.* (2009) argued that integration very often fails due to the conflicting interests of the supply chain members, and because of the lack of commonly accepted IT infrastructure and operation process to facilitate the flow of information and materials

between the companies. According to Bowersox *et al.* (1999; 2010), supplier integration is the key capability to successful SCI, while adopting lean manufacturing helps manufacturers and their suppliers establish common goals/strategies in carrying out organizational improvement.

Supplier integration concerns business process integration among manufacturers and suppliers through using IT applications. This is *transactional* in planning and operations that are supported by e-business systems, and involves *information sharing* in achieving decision synchronization and contract bounded *collaboration* with selected suppliers for risk sharing (Basu and Wright, 2008; Matopoulos *et al.*, 2009; Nurmilaakso, 2008; Simatupang and Sridharan, 2004). Effective information sharing along the supply chains could positively influence supply chain practice adoption: for example, JIT/lean manufacturing requires implementing pull systems, supply management and waste removal, which form the basis of SCI (Serve *et al.*, 2002; Zhou and Benton, 2007).

According to Bowersox *et al.* (1999, 2010), SCI concerns: *operations* that include traditional processes such as purchasing, production, and logistics where SCM practice like, JIT/lean, comes into play, *planning and control* that incorporates IT and planning systems, and measurement competency, and *behavioral* that relates to how relationships are managed, in which *supplier integration* in the operational context represents the driving force underlying the collaborative relationships among manufacturers and suppliers as a recognition of mutual dependences. Hence, supplier integration as a specific context of SCI may have a positive effect on adopting lean manufacturing as a SCM practice. Relevant ***supplier integration strategy*** can be developed, based on the capabilities of operational integration and supplier management (Bowersox *et al.*, 1999). Based on the work of Bozarth and Handfield (2008), competencies of supplier integration in three areas positively affect lean manufacturing adoption: *Information sharing* with suppliers including demand forecast, inventory level and production planning decisions, *E-business systems* that support collaborative communication and information sharing with suppliers, and *Policy-based supplier selection*, based on relevant measurements to help develop and manage long-term supplier relationships by evaluating suppliers' performance and their capability in providing innovations and co-design of products for meeting customer needs. According to Sahay (2003), SCI demands collaboration among all participants, whatever their size, function, or relative position, in which suppliers and manufacturers, as major partners, are two very crucial components of the chain where their

involvement calls for commitment and trust over an extended time period and which includes sharing of information, risks and rewards. There have been no studies that have been focused on lean manufacturing adoption in the aspect of value creation related to SCI effect concerning both internal and external supply chains, not to mention studying the supplier integration effect on its long-term adoption based on structural decision process. The next sub-section will explore the lean principles adoption in the services segment at the downstream supply chain process.

2.3.3 Lean services adoption

Lean principles have been proved to be an effective management system in manufacturing to improve overall efficiency and to enhance the work environment, in which the "getting more with less" concept can also be applied in other form of business (Aikens, 2011; Ohno, 1988; Russell and Taylor, 2009). Lean principles, as mentioned earlier, including eliminating waste, reducing complexity, improving efficiency, speeding delivery, and understanding customers, have been adopted beyond manufacturing in services and retailing (Heizer and Render, 2007; Russell and Taylor, 2009). Hence, becoming a lean enterprise has the potential to enable service companies or retailers with the capability to improve operations, reduce costs and deliver services with shorter lead times. Successful cases in lean servicing have been applied in some instances to insurance (Swank, 2003), healthcare (Miller, 2005), government (Gupta, 2004), and retailing (Heizer and Render, 2007; Russell and Taylor, 2009). Lean enterprises need to make changes to three dimensions in their operations to obtain improvement: ***standardization of tasks and procedures*** which can be achieved by, e.g. documenting the process flow, training, automating tasks, etc., such that people can be freed to spend more time being creative on value-added work, ***consolidating common processes*** to eliminate non-value-added cost and duplicative efforts that customers are not willing to pay for, and ***eliminating loop-backs or delay*** that will result in very low productivity levels (George and Wilson, 2004; Hanna, 2007; Swank, 2003).

In the past several decades, IT has continued to expand into key manufacturing and service delivery systems, and, in particular, into their process workflows and supporting procedures. This has arrived recently in retail applications that implement lean principles in services and retailing. According to Martin (2010), typical IT applications facilitate simplification, automation, integration, and monitoring of business processes, as well as

the management and control of material and information workflows which fully realized the lean thinking initiative. With the emergence of wireless computing, the "Internet of Things" is happening now where the things (e.g. people and assets) in organizations can be enabled with a wireless capability to provide visibility throughout the business and real-time viewing of inventories, movements, performance measurement, security and safety as the basis of business process improvements (Sarma, 2008). Radio Frequency Identification (RFID), a wireless technology, demonstrates Martin (2010)'s IT capabilities by realizing lean principles in downstream supply chains which brings profound process improvements in retail or service-oriented enterprises with a number of successful cases, for example, American Apparel (O'Conner, 2008), Levi Strauss & Co. (Wasserman, 2006), Marks & Spencer (Hess, 2008), and Wal-Mart (Roberti 2004, 2005, 2007). The real-time asset and personnel visibility enabled with process automation that realizes lean services in the "last 50 feet" of the supply chains, improves customer experience and item management in store execution and enables retailers to cope with customers with more sophisticated buying needs in today's fast-paced society as they have less time to devote to shopping (Hardgrave and Miller, 2008, Sarma, 2008). Voehl and Elshennawy (2010) argued that the behavior aspect of lean service adoption outweighs the technical aspect as a substantial change to current operations of a firm is required that involve not only the change of operating system and business processes, but also the participation of users such as staff and customers. Nevertheless, there is a lack of empirical study about the use and implementation of RFID technology in realizing lean services aimed at unveiling adoption factors in the behavioral dimension. Therefore, further studies of RFID-based lean service adoption in retailing and services are necessary for exploring the user experience of the implementation as well as the issues regarding the use and deployment of this emerging technology, providing insights into formulating relevant adoption strategies based on real-life experience for firms in different supply chain positions aimed at getting the buy-in from both end-users and management.

In summary, the preceding sub-sections discuss adopting lean principles in manufacturing and service/retailing, representing the respective form of business in the upstream and downstream supply chains. First, lean principles adoption in term of value creation was outlined by considering the SCI effect with a special focus on the influence of supplier integration on lean manufacturing. Second, understanding the user experience of the use and implementation of lean services in real-life are necessary as understanding the

behavioral aspect of adoption helps getting users' buy-in. Also, lean services adoption is compared and contrasted with the results of lean manufacturing studies which are not addressed by previous studies. The next section will discuss the research methodology for establishing reliable and valid evidence as well as evaluating the generalizability of the proposed theories in the present research.
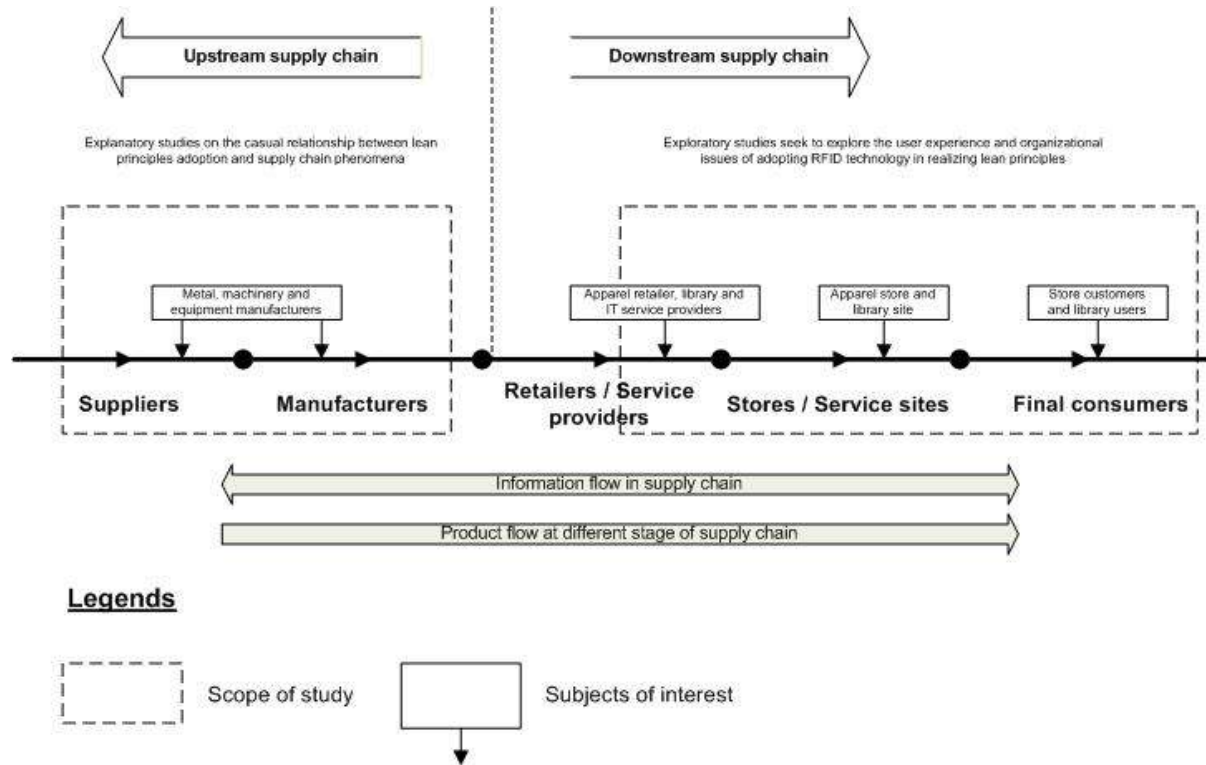

Figure 2.2 Scope of studies and research strategy

2.4 Methodology

Methodology refers to the way in which we approach problems and seek answers, and in social sciences, the term is applied to how research is conducted (Taylor and Bogdan, 1998). Two dichotomous theoretical approaches, i.e. quantitative and qualitative methodologies are used to take on different kinds of research questions (Gray, 2009). The methodology section contains three parts: the *research design* highlighting the research strategies and approaches that are used to deal with different kinds of problems in relation to the subjects' supply chain position, the *research process* which details the steps carried

out in the studies, and approaches to *measurement and assessment* concerning data collection and subsequent data analysis.

2.4.1   Research design

With the intention of covering the major players of the supply chain from upstream (e.g. suppliers and manufacturers) to downstream (e.g. retailers and customers of product/service), the behavioral intention of adopting lean principles by these supply chain members is explored with multiple methods by studying practical issues and user concerns about adopting new practice or technology. **Figure 2.2** illustrates the scope of studies and research strategy that correspond to the supply chain position of the research subjects.

The choice of research strategy is relevant to the form of research questions and type of event being studied (Gray, 2009; Saunders, 2007; Yin, 2009). Hence, defining research questions is the most important step in a research study. Yin (2009) argues that research questions consist of both substance (e.g., what is my study about?) and form (e.g., am I asking a "who", "what", "where", "why", or "how" question?), which are associated with the selected strategy and, ultimately, that affect the trustworthiness of the findings of the research study. Based on Gray (2009), Saunders *et al*. (2007) and Yin (2009), the relevant situations for different research strategies and approaches are summarized in **Table 2.1**.

Purpose	Theoretical perspective	Research strategy	Forms of research question
Exploratory	Non-positivism (qualitative)	Case study, action research, grounded theory, ethnography	What?
Descriptive			What?
Interpretive			What, how?
Explanatory	Positivism (quantitative)	Survey, experiment, case study	What, how, why?

Table 2.1 Relevant situations for different research strategies (adapted from: Gray, 2009, Saunders, 2007 and Yin, 2009)

According to Yin (2009), an exploratory study is initial research that tries to look for patterns in the data and comes up with a model within which to view this data. Research

questions for this kind of case-study can focus on "what" questions, and descriptive studies take this further and try to obtain information on the particular features of an issue. Research questions here can again focus on "what" questions. Interpretive studies seek to explore peoples' experiences and their view or perspectives of their experiences, and research questions aim to explore "what" a given experience is like, and "how" someone made sense of it (Gray, 2009; Saunders, 2007). An explanatory study continues this even further by trying to explain why or how something happens, or happened with the emphasis on discovering causal relationships between variables, where research questions in this case are of the "how" or "why" type (Gray, 2009; Yin, 2009).

Having reviewed 633 articles focused on studying the use of research approaches in technology adoption research, Dwivedi (2008) provided further information about other situations concerning choosing an appropriate research approach:

(a) The greater extent to which a researcher is part of the context being studied, the more relevant that a non-positivist (e.g. interviews, ethnography or observations) research approach was used.

(b) A non-positivist approach was used mostly for investigating the usage of technology that requires in-depth exploration of user experience and issues.

(c) The choice of approach corresponds with the unit of analysis. If the organization is considered as a unit of analysis, the case study approach is favored, while in studies relating to large sample size, a survey approach would be more feasible.

(d) Selection of the approach is influenced by the type of theory and models employed. In the case of a number of research hypothesis involved that require collecting quantitative data and statistical analysis for testing, the survey method is the only appropriate research approach that can be used.

(e) The sample size should be above 300 in performing rigorous statistical analysis, such as principal component analysis (PCA) and multiple regression analysis.

Seeking the facts about the causes of adopting lean principles by upstream manufacturers and suppliers demands identifying factors that exercise an external influence on people, including management, who make acceptance decisions, and individual users who use the new method in everyday work, aimed at concept generalization, here a positivist approach is relevant, leading to explanatory studies which require a quantitative research design (Dwivedi, 2008; Remenyi *et al.*, 1998; Taylor and Bogdan, 1998). On the other hand,

aiming to study the phenomenon about the application and implementation of RFID technology in realizing lean principles for companies in downstream supply chains, an exploratory study leading to a qualitative research design based on real-life settings is useful to explore the user experience and circumstances with a case study method (Dwivedi, 2008; Eisenhardt, 1989; Yin, 2009).
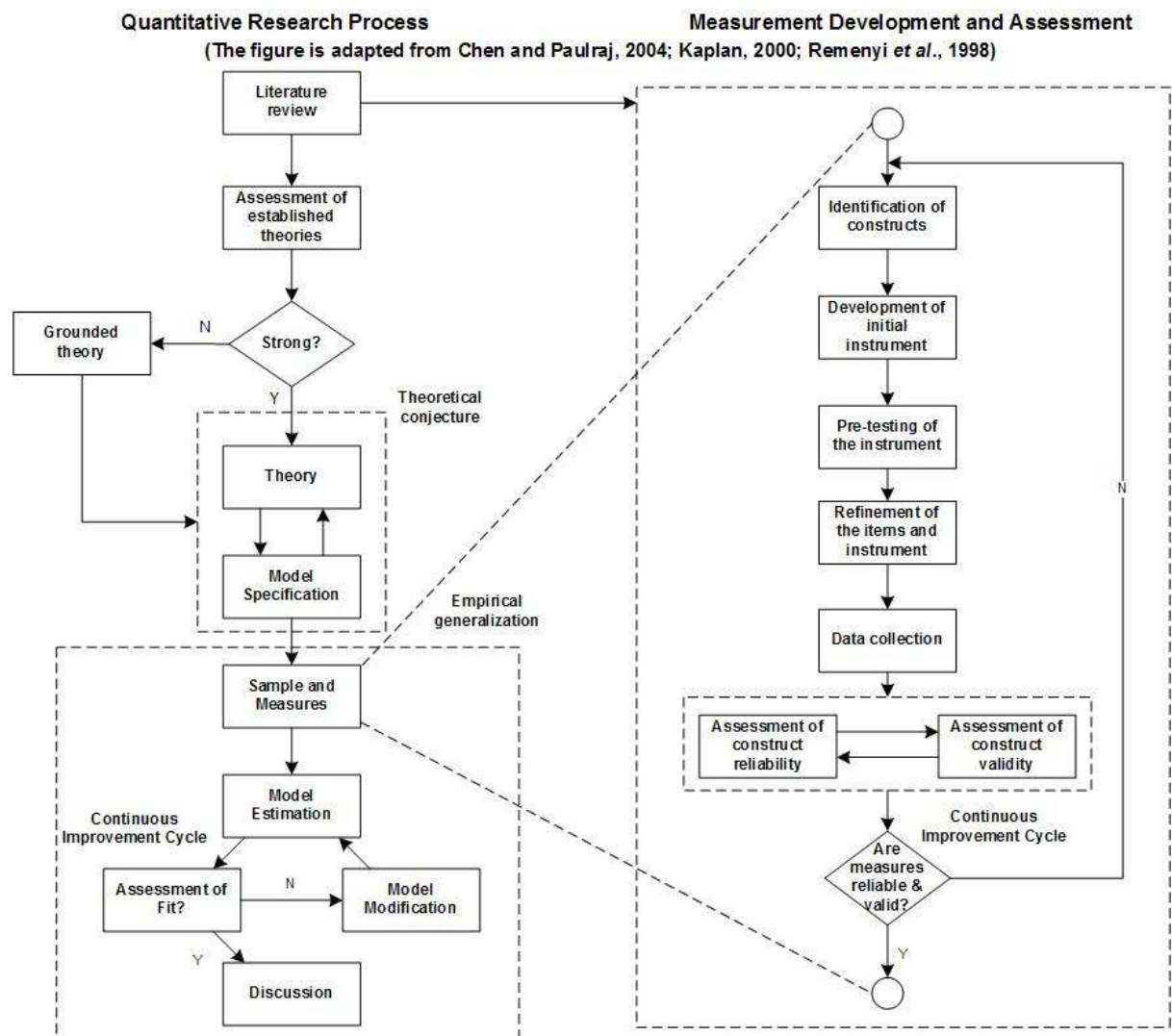

Figure 2.3 Quantitative research process

2.4.2 Research Process

The quantitative research process (Chen and Paulraj, 2004; Kaplan, 2000; Remenyi *et al.*, 1998) in **Figure 2.3** is adopted in the positivist part of the thesis to assess the research model in association with the measurement method that satisfies the requirements of reliability, validity and model fit respectively. The theoretical research process, which is commonly referred to as a 'waterfall' model, in which the flow found in many studies is sequential and linear, seldom works out in practice in such a simple and straightforward way (Remenyi *et al.*, 1998). Thus, a continuous improvement approach is adopted to assess the measurement reliability and validity in order to ensure that the target values of these measurements can be obtained before the assessment moved on to the next stage. Also, a similar procedure is performed on model estimations based on the same principle.

The details of the research process are: First, the theory, as represented by the research model with the hypothesized relationships supported by the literature review or established theories, if any, is presented. If no supporting theory can be identified, grounded theory (Glaser and Strauss, 1967) is used and empirical evidence is collected to establish directly the concepts and relationships which will be combined in the theory (Remenyi *et al.*, 1998). According to Glaser and Strauss (1967), grounded theory is an inductive, theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic, for example, the variables that describe the causal relationships of topic of interest, based on the empirical evidence. Next, a sample is selected and measures are obtained with the construct reliability and validity tested based on the methods provided in next section. This is followed by the estimation of model parameters. At this stage, the estimation model is obtained in which the goodness of fit is assessed, followed by necessary modifications. Once the model is proved to fit, the findings followed by limitations, implications and possibilities of conducting future study are discussed.

On the other hand, the qualitative research process (Remenyi *et al.*, 1998) in **Figure 2.4** is adopted in the non-positivist part of the thesis, in which the initial steps including *literature review*, *assessment of the established theories* and the use of *grounded theory* are the same as to the beginning part of the quantitative process. The steps aim at making sure the information generated in these qualitative steps, which is referred to as the narrative that describes the phenomenon or user experience, is sufficiently explicit and generally accepted by people in the field as relevant for the researcher to be able to develop a

workable and testable theoretical conjecture. Besides, exploratory studies can be conducted with field experts for the purpose of getting more insightful information in the topic areas for helping to pre-test the instruments used for data collection and the theoretical model before empirical generalization.
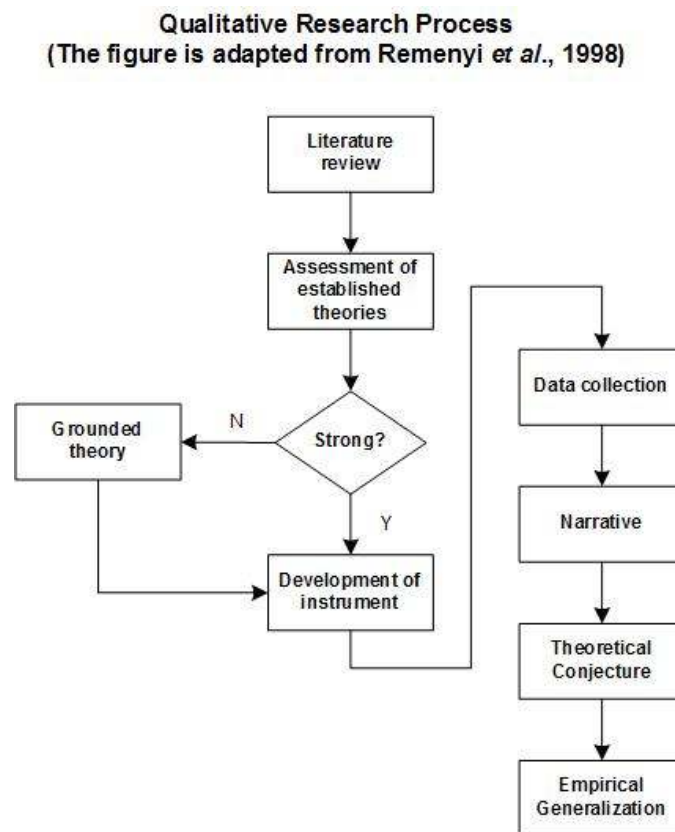
Qualitative Research Process
(The figure is adapted from Remenyi *et al.*, 1998)

Figure 2.4 Qualitative research process

2.4.3 Empirical data collection and assessment

(I) Data collection and measurement

Empirical research relies on the production and accumulation of evidence to support its findings, and the collection of evidence is one of the important steps in achieving this research strategy. According to Remenyi *et al.* (1998), the collection of evidence in relation to the underlying concepts and paradigms shapes and determines the evidence that is collected. Researchers need to obtain the relevant kind of evidence that is required in order

to develop and test a theory in a quantitative study which is then expressed in terms of hypotheses for empirical generalizations, or explain and understand a phenomenon contextually in an qualitative study which may be collected in a less instrumental way, for example, by observations (Bryman, 2008; Gray, 2004; Remenyi *et al.*, 1998). As indicated in Table 2.1, the kind of data collection method used is associated with a particular research strategy and the form of research questions in the study, and survey research is used in a quantitative study. The objective of such a quantitative study is to make generalizations about the subjects' behavior, attitudes and backgrounds, where structured interviews or sending out questionnaires can be the kind of survey method used for collecting evidence, where self-administered or self-completed questionnaires are appropriate for large samples (Bryman, 2008; Gray, 2004; Sanders, 2007).

Being one of the research team members in the International Manufacturing Strategy Survey (IMSS) (Lindberg *et al.*, 1998), the researcher works collaboratively with other members in the research network for making sure the principles were adopted in the questionnaire design and data collection processes. The empirical data gathered by the researcher not only supports his two quantitative studies in this thesis, but is also shared with other members for improving the questionnaire and method of sample selection as part of the research strategies. The questionnaire in the current study was designed to reveal the multi-facets of manufacturing strategy and practice. Data was collected from participating countries. The participating companies in the sample consist of 20 countries and 600 companies in the world, and the sample characteristics are detailed in the two quantitative studies. The companies are selected based on their financial and competitive strengths, with the ability to adopt a variety of advance manufacturing practices and to be among the first to bring technological advances. Also, they are responsive to the market through close collaboration with their suppliers in supporting these capabilities. Hence, it would be easier to compare them with their counterparts in the other countries based on these distinctive characteristics.

The method of collecting quantitative data is random sampling and phone contact is followed. The questionnaires are forwarded to the participating companies via mailing, fax or on-site interview. Participating countries send their data to the research coordinator who forwards the final database to all participants. Operationalization of research variables in the study is based on the self-developed items of the questionnaire and is substantiated by the literature review. Multiple items are used to measure the research constructs. The

researcher attempted to examine the items side-by-side with the intention of enhancing reliability of the measurement. All items are measured by a five point Likert scale and the corresponding measurements are detailed in Chapter 3 and Chapter 4. The questionnaire is listed in Appendix A.

The qualitative study aims to explain end-users' complex behavioral intention in using RFID technology for realizing lean services in the field and to establish valid and reliable evidence used for identifying adoption factors of this new application. The qualitative study helps in soliciting views from end-users and management on their experience of use and behavioral intentions to accepting RFID technology. The inductive approach of the qualitative study allows the design itself to evolve, develop and unfold as the research proceeds with the benefits of exploring new and unanticipated information to emerge from participants (Bryman, 2008; Cassell and Symon, 2004). The case study research method is used due to its strength in likely generating novel theory and replicating or extending the emergent theory (Eisenhardt, 1989). Besides, the exploratory nature of case study research helps the researcher better understand and explain complex phenomena (Remenyi *et al.*, 1998; Saunders *et al.*, 2007; Yin, 2009).

Aimed at understanding the respondent's point of view, semi-structured interviews were used in the field with front-line staff or customers involved in using the technology and those involved in making related decisions (e.g. managers). Triangulation was used to improve the validity of the study (Yin, 2009). Thus, staff members from end-user departments, management and the contractors who deliver service and support for RFID-based systems, were interviewed to compare and contrast the feedback from different groups. Moreover, informal observations were carried out on site where the researcher participated as a staff member or customer.

Based on Creswell's (1998) work, the following interview procedures were used to conduct the study:

(a) The researcher contacted the organization to be interviewed and asked for permission to interview staff, representatives from supplier and customers randomly selected by the researcher;

(b) Once the names and contact information of the subjects were provided, the subjects were contacted to set up the time and location for the one-on-one interview;

(c) The customer who has experience using the RFID technology or associated systems was randomly selected on-site and, subsequently, interviewed by the researcher;

(d) Before the interview, the researcher gave a brief explanation of how the interview was going to be conducted and reminded the participants that the interview and all the related materials would remain confidential;

(e) During the interview, the researcher served as an active listener, interjecting only to clarify a question or ask for clarification of the participant's responses.

After the interview, the researcher thanked the participants for their time and participation and asked them for permission to follow up via phone, email, or in person, if there was a need to.

(II) Data analysis

Both quantitative and qualitative data analysis methods were used to evaluate validity, reliability and generalizability of the estimates, based on the empirical evidence collected in the studies. Rigorous statistical methods are used in the positivist part of the thesis to analyze the survey data, while content analysis is used in the non-positivist section for analyzing the information generated in the qualitative studies. Following the development of theoretical conjecture, the constructs of the hypotheses are operationalized and empirically tested in the positivist section. A comprehensive quantitative data analysis approach adapted from Chen and Paulraj (2004), concerning the assessment of research constructs and theoretical models, is developed. A three stage assessment process is proposed to test the reliability and validity of research constructs, and the fitness of theoretical models:

Assessment of reliability

Reliability is frequently defined as the degree of consistency of a measure. In the first stage, Cronbach's alpha method is used in reliability analysis and alpha coefficient was created for each construct. An alpha coefficient is typically considered adequate if it exceeds 0.7 (Bagozzi and Yi, 1988; Chen and Paulraj, 2004; Cronbach, 1951; Nunnally, 1978), and this implies that similar results will be obtained on different occasions and the concern, is therefore, with how replicable is the research study (Remenyi *et al.*, 1998). Alpha value of 0.6 remained acceptable in exploratory research, while items that contributed least to the

overall internal consistency were the first to be considered for exclusion (Chen and Paulraj, 2004; Hair *et. al.,* 1998).

Assessment of validity

In stage two, construct validity is examined in the quantitative studies (Chen and Paulraj, 2004; Hair *et al.*, 1998). Construct validity is the degree to which the original constructs in the theory section and the variables in the empirical section align (Mayer, 2009). If these two elements are strongly matched, then the study is considered to have high construct validity. If, however, the theory revealed is disconnected from the data analysis, then the construct validity is low, as studies with low construct validity are not actually supporting the theoretical relationships that they purport to examine. Factor analysis is used for testing construct validity. Since the number of constructs has to be determined prior to the analysis, the exact number of factors to be extracted is expected to be provided in the analysis. According to Chen and Paulraj (2004), indicators items will be discarded after comparing their loading on the construct they were intended to measure to their loading on other scales, while nuisance items will also be deleted from consideration in the study. Besides factor loading, an important measure that is consulted in factor analysis is the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy for detecting if the data factored well, which ranges between 0 and 1 with 0.5 as minimum acceptable value, and the greater the KMO value the more effective the factor analysis is likely to be (Kaiser, 1974; Remenyi *et al.*, 1998).

Convergent validity and discriminant validity are both examined in the evaluation of construct validity (Chen and Paulraj, 2004). Convergent validity represents how well the item measures related to each other in representing a concept (Swafford *et al.*, 2008). Factor loading exceeding 0.60 demonstrates good convergent validity (Gyampah and Salam, 2004; Hong and Zhu, 2006). Hair *et al.* (1998) noted that factor loadings of constructs are proportional to sample size and the factor loadings for sample size of 350 or above exceed 0.30, while factor loadings of 0.55 or above are significant enough in a sample of 100 respondents, and the greater the respondent number the lower the factor loadings are needed. Last, but not least, discriminant validity occurs when measures of each construct are distinct from one another (Campbell and Fiske, 1959). The model demonstrates discriminant validity if the square root of the average variance extracted (AVE) by each construct exceeds the corresponding inter-variable correlation (Fornell and

Larcker, 1981). AVE is the average squared factor loading. AVE of less than 0.5 indicates that on average, more error remains in the items than variance explained by latent factor structure imposes on the measure (Fornell and Larcker, 1981; Hair *et. al.,* 1998).

Assessment of model fit

In stage three, theoretical models containing a series of hypothesized cause-effect relationships are assessed for generalizability. For models having limited dependent variables, multiple regression analysis (MRA) comes into play, generally expressed as **Equation (2.1)**, where α is a constant, β_x is coefficient of x and x is an independent variable, and lastly, ε is an error term. The approach obtains the explanatory power of each independent variable separately and the significance of the hypothesized relationships for determining the fitness of the proposed conceptual model through evaluating the significance of multiple correlation coefficients, i.e. R^2 and the β values (Pedhazur and Schmelkin, 1991).

$$y = \alpha + \beta_x x + \varepsilon \qquad (2.1)$$

Grounded in adequate samples and significant correlation among the constructs of interest, the causal relationships among lean principles adoption and its antecedents are evaluated by using MRA. Adapted from Allison (1999) and Allen *et al.* (2009), a two step approach of MRA is used to assess: (1) the goodness of predictions, and (2) the goodness of coefficient estimates. In step one, the goodness of predictions is assessed by testing the significance of R^2, representing the degree of reduction in the prediction errors. Based on Allison (1999), and Chen and Paulraj (2004), R^2 value between 0.28 and 0.3 is acceptable, and *F*-test is followed to further test its significance. In step two, the significance of the β weights in each predictor variable is evaluated with a *t*-test for evaluating the goodness of coefficient estimates.

For complex models with multiple dependent variables, the *Structural Equation Modeling* (SEM) method is used to evaluate the causal relationships, in which the relationships are described by parameters, that is, the path coefficients indicating the magnitude of effect that independent variables have on dependent variables (Hershberger *et al*., 2003; Jöreskog and Sörbom, 2003). By translating the hypothesized relationships into testable mathematical models, SEM offers a comprehensive method for testing the models against

empirical data which is commonly referred to as the confirmatory mode of SEM analysis (Hershberger *et al*., 2003). Based on Eye and Fuller (2003), Kaplan (2000) and Hershberger *et al*. (2003), the models are generally described by a system of structural equations which can be compactly written as:

$$y = \alpha + By + \Gamma x + \zeta \qquad (2.2)$$

To fix notation in **Equation (2.2)**, let p be the number if dependent variables and q be the number of independent variables. Hence, y is a p x 1vector of observed dependent variables; x is a q x 1 vector of observed independent variables, α is a p x 1vector structural intercepts, B is a p x p coefficient matrix that relates dependent variables to each other, Γ is a p x q coefficient matrix that relates dependent variables to independent variables, and ζ is a p x 1 vector of error terms. Eye and Fuller (2003) noted that there are three popular software packages available for SEM models, which are, in alphabetical order, Amos (Byrne, 2001), EQS (Bentler and Wu, 1995) and LISREL (Jöreskog and Sörbom, 1993). The established hypotheses are tested with one of the software packages. Insignificant paths are deleted from the proposed model if it does not fit well and retested. A two-step process is adapted from Hu and Bentler (1999) to test the model fitness, which: (1) examines the significance of path and measurement coefficients, and (2) examines the model fit by using multiple criteria to evaluate model fit indexes for prediction which include nonnormed fit index (NNFI), and comparative fit index (CFI) ranging from 1 (perfect fit) to zero (not fit), with other descriptive fit statistics including chi-square (χ^2), and root mean square error of approximation (RMSEA) generated from the software. Lastly, the detail descriptions of these model assessment statistics are given in **Table B1** of **Appendix B**.

In the non-positivist section, qualitative content analysis of the narratives of interviewees and the text recorded in the observations on using lean services and RFID technology, is used to extract the underlying attributes of user perceptions. Also, the method is used to analyze the supporting literature by extracting meaning, sorting categories and formulating themes (Bernard, 2010; Carson *et al*., 2001; Graneheim and Lundman, 2004). The findings essentially represent experience and expectation from the end-user perspective which are compared and contrasted with the practical design and implementation experience of the product developer so that a realistic adoption approach can be developed. The adoption factors are identified based on the findings. The process of the content analysis method is

based on the steps adapted from Carson *et al*. (2001), Graneheim and Lundman (2004), and Miles and Huberman (1994), which cover the following procedures:

(a) coding the scripts obtained from the interviews;

(b) adding comments and reflections;

(c) going through the scripts to identify similar phrases, patterns, themes, relationships, sequences, differences;

(d) summarizing and categorizing these patterns, codes, etc.;

(e) gradually elaborating a small set of generalizations that cover the constancies recognized in the data; and

(f) linking these generalizations to a formalized body of knowledge in the form of constructs or theories.

The findings obtained from staff members essentially represented experience and expectation from user perspectives which can be compared and contrasted with the data obtained from other sources, e.g. customers and suppliers, so that a realistic recommendation and conclusion can be drawn. Besides, the results will be used for not only producing self-developed variables in the development of an instrument but also possibly model building in the establishment of theoretical conjecture that aims to create new concepts, which is demonstrated in Chapter 3.

Examination of validity, reliability and generalizability remain as important quality assurance procedures for non-positivist research, in which the criteria developed for positivist research designs are still applicable, in order to evaluate how well the research will be acceptable to a critical audience of peers and assessors or examiners, but given the nature of non-positivist approaches to research, the yardsticks are therefore different (Remenyi *et al.*, 1998). According to Yin (2009), reliability and validity should be established for case study research, in which pilot-testing the questionnaire with experts in a similar area can help enhance the reliability, while the validity issue can be resolved by using multiple sources of evidence, for example, using triangulation method is a way to improve the validity of the studies. Lastly, the evidence gathered from case study research is not normally used to generalize into theory, as it deals with more particularization which is rather used in expanding, modifying and refining theory, suggesting complexities for

further investigation, as well as for revising the theoretical propositions outlined at the beginning of the case study (Ridder *et al.*, 2009; Yin, 2009).

Based on the research design, in this thesis, explanatory studies on adopting lean principles in manufacturing firms in upstream supply chain are pursued for the first two studies, in which SCI as antecedent of adoption in the causal relationship is evaluated with a quantitative research approach based on the empirical evidence obtained from 558 manufacturers in 17 countries. On the other hand, exploratory studies on RFID technology adoption in realizing lean services in downstream supply chain are conducted with the organization as the unit of analysis. As in-depth exploration of user experience on using this emerging technology at the end-user touch points is relevant for the last two studies, case study research on two business cases is used to explore the adoption factors and examine the organizational readiness effect on RFID implementation.

2.5   Summary of literature review and methodology

In summary, the literature review suggests using mixed-methods research that covers both qualitative and quantitative methods, to study lean principles adoption with reference to firms' supply chain position, as it concerns creating business value in manufacturing (upstream) and service operations (downstream) which associate with different types of research questions. Upstream supply chain activities are characterized by supply management and production which is where lean manufacturing comes into play. SCI integrates these value-adding activities as the basis of adopting lean manufacturing, in which supplier integration as a specific context of SCI in the upstream supply chains, addressing the demand generated at downstream. Downstream supply chain activities at the customer touch points reflect customer values through efficient store execution and appreciation of customer experience, and synchronize all the way back with the upstream activities through the integrated mechanisms, for example, *e-kanban* and/or other IT applications in the EMSC. No matter the antecedents in the causal relationships of lean manufacturing adoption, or the adoption factors of RFID technology that realizes lean services, the influential factors should be incorporated into relevant organizational strategies in order to properly align with the original purpose of adopting lean principles for operational improvement. Besides, understanding the motivations of supply chain stakeholders to adopt/reject lean principles could help better implement this innovative practice in the firms along the supply chains. Finally, at the end of the literature review,

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empirical research methods that are relevant to the current study were reviewed for establishing valid and reliable evidence, and testing the generalizability of the theories for a larger population.

The next four chapters consist of refereed journal articles that have been published. The first article has been published online by the *International Journal of Production Research* but the schedule on when it is going to be published in paper form is still not available. The other three articles have been published in the *International Journal of Sustainable Economy*, *International Journal of Services Sciences*, and *International Journal Technology Intelligence and Planning* in both paper and online form. The first article presents the analysis of the causal relationships of lean manufacturing adoption and EMSC-enabled SCI, with particular focus on business value creation. Based on the first article, the second article moves a step forward to evaluate the effect of supplier integration, a specific context of external SCI, on the on-going adoption of lean manufacturing. Both studies identify the antecedents of lean adoption through evaluating the technology enablers of EMSC in upstream supplier chains. In addition, the adoption was analyzed based on three complementary *JIT* management competencies, i.e. system, technology and people. The last two articles study the realization of lean principles in services with RFID technology, a mobile technology that delivers context-aware applications, in retail and services firms that represent the end-user touch points in downstream supply chains. The third article analyzes a successful case to identify the adoption factors of this emerging technology by exploring the user experiences of selected subjects. A business value-added framework that supports the lean improvement objectives is developed based on these factors. The final article conducts an analysis of a failure case in relation to adopting RFID in library services for cost saving by streamlining operations and improving customer values through offering intelligent services. However, user privacy in handling customer information was exploited due to the change of workflow, which reveals that organizational readiness could be a critical factor in adopting innovative practices in business. The issue was subsequently resolved with proper remediation procedures.

Chapter 3   AN EXTENSION OF IDT IN EXAMINING THE RELATIONSHIP BETWEEN ELECTRONIC-ENABLED SUPPLY CHAIN INTEGRATION AND THE ADOPTION OF LEAN PRODUCTION

The first article was published in the *International Journal of Production Research* (So and Sun, 2010a) and studies the relationship between electronic-enabled SCI and the adoption of lean manufacturing. As indicated in Chapter 1, the research conducted by the first author, i.e. the researcher, who is the sole investigator of his study, was fully funded by a research grant at City University of Hong Kong managed by the co-author. The first author is the only research staff recruited with this funding. The lean manufacturing adoption is studied based on Buker (1991)'s JIT implementation approach of streamlining processes, executing pull production, empowering workforce, and restructuring supply strategy. With reference to Rogers' (1983) relative advantage concept, i.e. the value of lean manufacturing, as intermediate variable, a theoretical model is established to explain the causal relationship, in which value is customer oriented which represents reduction of price and delivery speed, and business oriented including reduction of cost and inventory.

SEM was used to test the relationship that involves multiple dependent variables. The results show that SCI, combing both organizational integration and supplier integration, positively influences the value of lean manufacturing in the EMSC environment by making the value stream flow in the supply chain and determine the adoption. Electronic connectivity enables EMSC to execute interorganizational processes, integrate with trading partner operations, moving them from organization-centric supply chains towards synchronized electronically-connected supply chains, and form the basis of the kanban-linked supply chain to support the customer pull initiative. Ohno (1998) emphasized that process automation in lean manufacturing demands individual skill and teamwork of the workforce. Empowerment of the workforce with this capability is important for the implementation success of lean principles in establishing a fool-proof production system. Here staff performance essentially represents the value by the perceived usefulness of lean manufacturing, and the results show that the bottom line of manufacturers will be improved as a result of these improvements.

These findings have not been discussed in any previous studies on lean manufacturing adoption, and further, the findings suggest that collaboration of manufacturers and suppliers, through the joint investment of the EMSC, is essential as representing the mutual commitment and benefits of executing the operations over this common platform.

An extension of IDT in examining the relationship between electronic-enabled supply chain integration and the adoption of lean production

Abstract:

Lean is proved to be an effective tool for companies to improve continuously and is widely studied from both practical and theoretical perspectives. However, most previous studies of lean production are limited to internal operations of a company. The research in this paper aims to explain the relationship between electronic-enabled supply chain integration and the adoption of lean production. A theoretical model with six hypotheses was proposed based on the Innovation Diffusion Theory (IDT). The model was empirically tested with data from 558 manufacturers. The results show that: (1) IDT can explain lean production adoption; and (2) electronic-enabled supply chain integration positively influences the perceived relative advantage of lean production and consequently leads to its long-term adoption. This study uses IDT to explain lean production adoption with the influence of electronic-enabled manufacturing supply chain (EMSC). The study also has practical implication that may change the supply policy in future practices, as companies may require their suppliers to implement EMSC as part of the lean production requirements.

3.1 Introduction

Bayou and Korvin (2008) simply defined, "to be lean is to cut fat" which pinpointed accurately the purpose of this contemporary management philosophy. Lean principles preach simplification and elimination of wasteful processes, which are applicable to overly-complex and non-integrated organization processes that are inefficient and provide little added value to customers. Becoming a lean enterprise enables manufacturers to improve throughput, reduce costs, and deliver shipment with shorter lead times. Today, manufacturers deal with more complex and longer supply chains, yet customers demand higher product variety at lower cost and shorter lead times. Manufacturers realize that non-integrated manufacturing processes and poor relationships with suppliers and customers in the supply chain are inadequate. The lean enterprise cannot afford low visibility or poor coordination across its global manufacturing supply chain. New method is needed for manufacturers to stay competitive in their markets. Supply chain management (SCM), a set of integrated approaches helps manufacturers improve the total effectiveness of planning and operations from procurement of raw materials to producing and distributing the final products through better coordinating the use of resources in the supply chain including systems, finance, people and facilities (Cooke, 1997; Rudberg and Olhager, 2003; Simchi-levi *et al.*, 2008). Extending lean principles from internal plant operations to SCM can leverage the supply chain's competitiveness further with increased responsiveness to demand change and reduced operating costs (Oliver *et al.*, 1993; Ryan, 2001). With a global manufacturing supply chain involving more participants today than ever before and due to the fast moving global market and capacity downsizing, managing increasingly complex supply chain activities and manufacturing operations with information systems becomes a burgeoning way to realize lean principles in manufacturing (Hugos, 2003; Pagatheodrou, 2005; Bayou and Korvin, 2008; Simchi-levi *et al.,* 2008).

An information system is a set of interrelated components that collects (or retrieves), processes, stores, and distributes information to support decision making, coordination, and control in an organization (Laudon and Laudon, 2004). Information systems used in an electronic-enabled manufacturing supply chain (EMSC) include the Internet and Electronic Data Interchange (EDI) which enable data transfer among manufacturers and supply chain counterparts as well as Enterprise Recourses Planning (ERP) systems which underpin managerial planning and provide functionality to summarize and analyze

business information for supporting daily operations and decision-making (Hartono *et al.*, 2007; Yao *et al.*, 2007). Aiming to improve internal efficiency, application of ERP systems in manufacturing, particularly in production planning and supply management becomes wide spread (Kotha and Swamidass, 2000; Somers and Nelson, 2003; Cagliano *et al.*, 2006). An EMSC offers lean manufacturers an environment with speedy data communication and reliable information management. Rogers (1983) contributed in the diffusion of innovation research and defined diffusion as the process by which an innovation is communicated through certain channels over time among the members of a social system. Information systems accelerate the diffusion of lean production as innovation across manufacturing supply chains. Hence, the degree of information systems diffused into manufacturing supply chains may influence the continuous development and long-term adoption of lean principles in manufacturing.

The goal of this study is to provide manufacturers with insights on implementing and adopting lean production in an EMSC environment. Hence, the adoption of lean production is explored in two dimensions, i.e. EMSC integration and perceived relative advantage of using lean production. In the forthcoming sections, we present supportive literature, establish a theoretical model on the adoption of lean production, empirically test the model based on the survey data from 558 global manufacturing firms in 17 countries, and propose aspects that lead to better implement lean production.

3.2 Literature review

3.2.1 Lean principles in manufacturing

Lean thinking start-off in manufacturing representing the meaning of "manufacturing without waste", and waste can be anything other than the minimum amount of equipment, materials, parts, and working time that are essential to production (Taj, 2008). Creese (2000) defines lean differently as "a manufacturing philosophy to shorten lead times and reduce costs by redirecting waste and improving employee performance, skills and satisfaction". Lean production is essentially a manufacturing approach that includes an integrated set of activities designed to achieve high-volume flexible production comparable to mass production but using minimal inventories of raw materials (Womack *et al.*, 1991; Hines, 1996; Wang, 2008).

Lean production was originated in Toyota with names "Toyota production system (TPS)"

or "just-in-time (JIT)" manufacturing beginning back in 1960s (Wu, 2003; Bruun and Mefford, 2004; Reichhart and Holweg, 2007; Taj, 2008). JIT manufacturing aims to eliminate waste and improve production in a continuous approach such as having only the required inventory when needed, reduction of lead times by reducing setup times, queue lengths, and lot sizes such that these activities are accomplished at minimum cost, and it encompasses the successful execution of all manufacturing activities required to produce a final product, from design, engineering to delivery, and includes all stages of conversion from raw material onward (Cox and Blackstone, 2002). Considering the ability to do more with less, JIT manufacturing is referred as lean production (Bozarth and Handfield, 2008).

There is no fixed practice for companies to follow to become lean (Bayou and Korvin, 2008). Contemporary manufacturing practices including JIT, pull production system, cellular manufacturing, standardization of manufacturing process, lot-size reduction, supplier networks, and workforce empowerment are all considered as key approaches (Bayou and Korvin, 2008; Hines, 1996; Pérez and Sánchez, 2000; Wu, 2003; Taj, 2008; Wang, 2008). However, researchers seldom adapt these approaches systematically to perform evaluation on lean implementation in manufacturing. Buker (1991) established a structural JIT implementation approach which focused on three management areas to systematically adopt JIT in manufacturing:

(i) **Technology management** concerns the implementation of a responsive production system for JIT manufacturers. It involves improvement on existing manufacturing processes through streamlining, reorganizing or restructuring the layout and set-up, e.g. using cellular layout, so that waste can be reduced and response time can be minimized.

(ii) **People management** focuses on the development of human capitals to support continuous improvement objective in JIT through creating proper work environment for employees from the president to the hourly workers towards this objective. This includes empowerment and training of workforce or establishing autonomous teams.

(iii) **Systems management** addresses the effective distribution of parts and materials as well as proper application of limited enterprise resources which may involve restructuring supply strategy such as forming a partnership or network with suppliers and establishing pull production systems such that parts and materials can be produced on demand with very short lead times.

JIT is a production philosophy based on the elimination of all waste and on continuous improvement of productivity which is synonymous with lean production (Cox and Blackstone, 2002). Buker (1991)'s JIT implementation approach can be adapted as the lean implementation practice. Pull production approach and kanban control systems are at the heart of these efforts (Wu, 2003; Bruun and Mefford, 2004; Taj, 2008). Kanban uses a simple signaling mechanism such as cue cards that materials or parts need to be replenished, and all production and movement of materials are controlled by the cue cards (Cutler, 2005; Bozarth and Handfield, 2008). Lean manufacturers today use kanban to drive a process to make, move, or buy the appropriate parts (Cutler, 2005; Taj, 2008). Kanban becomes a fundamental building block of a pull replenishment system, while implementing kanban linked-supply chain in a pull production environment enables manufacturers to maintain low stock levels while simultaneously improving the capability to deliver (Wu, 2003; Black, 2007; Taj, 2008).

3.2.2 Lean production in an EMSC environment

Lean production concerns not only with internal manufacturing processes, but also with the operation of the entire supply chain (Oliver *et al.*, 1993; Yusuf and Adeleye, 2002). Having conducted a global study on lean operation with 12 first-tier auto-component suppliers, Ryan (2001) argued that employing supply chain information systems might be an effective method for manufacturers to reduce increasing supply costs and to enhance buyer-supplier relationships through managing information and communication in the supply chain on a real-time basis. EMSC is a manufacturer centric supply chain in an e-Business environment which comprises (1) internal supply chain coordinating production management and organization functions, and (2) upstream supplier network in part of the external supply chain (Li, 2007).

An internal manufacturing supply chain includes five major organization functions: (1) material management; (2) production; (3) supply management; (4) sales and distribution; and (5) finance and accounting. According to Li (2007), ERP systems are used to coordinate decision making in the internal supply chains through integrating the entire company's information system, process and store data that cut across various functional areas, business units and production lines. As a supply chain information system, ERP influences the way manufacturers manage their daily operations by facilitating the flow of information among all supply chain processes of a firm that accelerates internal process

integration and enhances job performance. This agrees with the starting point of the concept of the TPS through improving the capabilities of workforce (Sugimori *et al.*, 1977).

An upstream supply network consists of all organizations that provides materials or services, either directly or indirectly to manufacturing firms. Manufacturers can often gain a competitive advantage with e-procurement systems through automating routine procurement activities in the order cycle including purchase order preparation, follow-up and expediting, invoice and payment and record maintenance (Bozarth and Handfield, 2008). E-procurement is a technology solution that facilitates corporate buying. It streamlines the purchasing process through pervading the traditional procurement steps identified through re-routing the flow of information and document over this common platform with the added value of eliminating waste generated in the paperwork (Presutti, 2003). An e-procurement system enhances the breakdown of the traditional vertical structure, and shifts management's focus toward horizontal processes and the empowerment of individual employees in the supply chain (Neef, 2001). With an e-procurement system, authorized employees of manufacturers can order parts and materials directly from suppliers where transactions are conducted in conjunction with other EMSC information systems including EDI, Extranet and the Internet (Pérez and Sánchez, 2000; Bruun and Mefford, 2004; Li, 2007). Flow control and replenishment of materials are the key supply chain processes in focus after procurement. Kanban is a lean production tool controlling material flow which extends the reach of manufacturers from upstream suppliers to downstream customers (Black, 2007). With the emergence of information technology, manufacturers migrate from kanban to e-kanban on existing ERP platforms with improved scalability which makes it easier to apply the replenishment methodology to more and more suppliers by connecting to EDI and the Internet (Bozarth and Handfield, 2008; Waters, 2009). The integration of kanban and ERP offers the benefit of combining the planning capabilities of ERP with the control capabilities of Kanban which creates and maintains more accurate information for implementing lean production in the EMSC (Bozarth and Handfield, 2008). Lean manufacturers can hence more tightly integrate with their supply chain counterparts.

Nevertheless, there is a lack of rigorous empirical study explaining the relationship of supply chain integration with manufacturers' perceived values of lean production, not to mention revealing the influence of EMSC on the long-term adoption of lean production.

3.3 Theoretical model and hypothesis development

Basing on Buker's JIT implementation approach (Buker, 1991), Li's EMSC model (Li, 2007), Rogers' IDT (Rogers, 1983) and the believe of supply chain information systems as the enabler of supply chain integration based on literature review, an integrated model was developed attempting to fill this gap through the survey with 558 manufacturing firms.
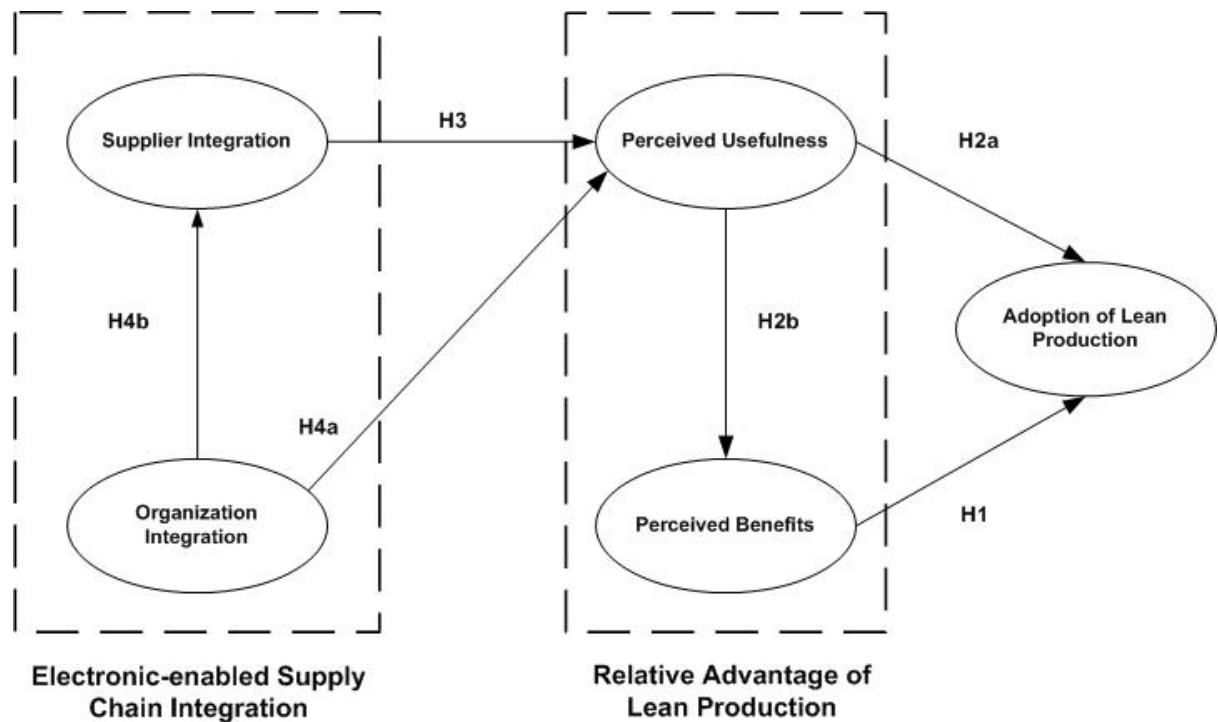

Figure 3.1 Theoretical model

Figure 3.1 shows that the theoretical model consisting of four indicating factors that influences lean production adoption. The two-tier model examined the association of lean production systems adoption with the perceived relative advantage of using this production philosophy where the perception was influenced by the readiness of EMSC in the aspect of supply chain integration. On this ground, six hypothesized relationships were developed and are elaborated below.

3.3.1 The adoption and relative advantage of lean production

Rogers (1983) emphasized that having a new idea adopted, even when it has obvious

advantages, is often very difficult which may normally take quite a lengthy period and may fail in the process of adoption. Implementing lean principles in production brings radical changes to not only the manufacturing operations, but also other areas such as supplier coordination, internal processes in various business units and even the day-today works of all staff members in the company. Therefore, identifying corresponding adoption factors and finding ways to speeding up the rate of adoption that potentially influence the adaptation outcomes is a manufacturers' top priority. Rogers (1983) identified "relative advantage" in IDT as a primary factor affecting the adoption of innovation where economic benefit was used as the measurement for comparing the advantage of new practice with a previous practice. Moore and Benbasat (1991) added "perceived usefulness" as the second measurement where the attribute was carried from the studies by Davis (1989) and Davis *et al.* (1989) with the belief that innovative ideas could enhance job performance. Hence, we adopt both "perceived benefits" and "perceived usefulness" as the measurement scales of relative advantage.

(I) Perceived benefits

Perceived benefits are the anticipated advantage of lean production to manufacturers measured by economic profitability which was identified in previous studies as key factor motivating adoption and use of new practices (Rogers, 1983; Moore and Benbasat, 1991). It was argued that perceived benefits of adopting technology practices at the organizational level were in many cases considered as the major factors influencing top management's investment decision (Chwelos *et al.*, 2001; Yao *et al.*, 2007). Since an expected outcome of adopting lean production is to improve bottom-line through cost reduction, using lean has anticipated advantage over the previous practice (Rogers, 1983; Cox and Blackstone, 2002). This leads to our first hypothesis H1:

H1: Lean production adoption is positively associated with its perceived benefits

(II) Perceived usefulness

Moore and Benbasat (1991) noted that Davis (1989) undertook a stringent instrument development process resulting in this scale with eventual reliability in excess of 0.90. According to Moore and Benbasat (1991), the scale was widely adopted in measuring relative advantages of accepting new ideas in terms of job performance enhancement. Thus, the scale was well substantiated in previous studies. Lean production must be perceived to

fulfill its intended purpose better than the precursors if it is to be used and adopted (Rogers, 1983; Moore and Benbasat, 1991; Creese, 2000). Therefore, perceived usefulness was adapted as the scale to measure lean production adoption. Hence, H2a was hypothesized as:

H2a: Lean production adoption is positively associated with its perceived usefulness

By adopting lean production, improvement would attribute to the job performance of manufacturing workforces and cost structures through reducing waste so that manufacturers' overall productivity can be increased (Womack *et al.*, 1991; Creese, 2000; Taj, 2008), which leads to improve economic benefits as perceived by manufacturers comparing to the previous practice (Rogers, 1983; Moore and Benbasat, 1991). Thus, we hypothesized H2b as follows:

H2b: The perceived benefits of lean production is positively associated with its perceived usefulness

3.3.2 Electronic-enabled supply chain integration

(I) Supplier integration

Supplier integration is an area of interest in the context of e-business technologies. This focus is motivated by the fact that manufacturing firms typically spend 55% of earned revenue on purchased products and services (Bozarth and Handfield, 2008). Guimaraes *et al*. (2002) empirically examined the critical factors that account for the performance of supplier networks. Their theoretical framework hypothesized that supplier network performance is positively influenced by the effectiveness of information technology used and the depth of supplier integration. The empirical results support their hypothesis. More recently, Cagliano *et al.* (2006) conducted a study on lean production practices adoption of 425 manufacturing firms. The results showed that lean production adoption has a strong association with the integration of information flows with external suppliers. In fact, supplier integration is a major step of lean production implementation strategy used by many companies (Black, 2007). EMSC, a supply chain infrastructure, enhances information management of both manufacturers and suppliers that essentially helps improve the performance of lean manufacturers in the aspect of supplier integration. This

leads to the following hypothesis:

H3: The degree of supplier integration using EMSC positively affects the perceived usefulness of lean production

(II) Organization integration

The success of lean production implementation demands a high degree of integration of manufacturers' internal organization processes including all the classic business functions, such as accounting, finance, purchasing, sales and operations as well as particular production activities including material management and production planning and control. ERP systems are designed to pull together all of these functions and activities into a single, tightly integrated package that uses a common database which facilitate end-to-end information flow supporting lean production (Bozarth and Handfield, 2008).

Cagliano *et al.*'s (2006) study also showed that the adoption of lean production practices has a strong association with the integration of information flows within the company. ERP systems as part of EMSC enabling the integration of information flow among manufacturers' internal processes, we expect adopting lean production helps improve manufacturers' workforce performance. Therefore, H4a was hypothesized as:

H4a: The degree of EMSC enabled organization integration positively influences the perceived usefulness of lean production

Grounded on Cagliano *et al.* (2006), EMSC supported organization integration would influence the manufacturers-suppliers integration over the same EMSC infrastructure. EMSC can be a common platform that provides centralized database as well as information hub for sharing of and controlling the flow of information, among not only manufacturers' internal processes but also their supply chain counterparts in supporting the lean production practice. Hence, we hypothesize H4b as:

H4b: The degree of EMSC enabled organization integration positively influences supplier integration using EMSC

The preceding hypotheses were empirically tested. The following section provides the details of research methodology.

3.4 Methodology

3.4.1 Data collection and sample

The data sample for this research was derived from the International Manufacturing Strategy Survey (IMSS), a research carried out by a global research network aimed at exploring practice and performance in manufacturing and SCM (Lindberg *et al.*, 1998). The project was initiated by London Business School and Charlmes University of Technology in 1992. According to Lindberg *et al.* (1998), the research network consists of 20 countries and 600 companies around the world, including developed countries, i.e. USA, Japan, British, Germany, and developing countries, i.e. China, Argentina, Mexico. The participant companies in the sample operate in the engineering industry and manufacture metal products, machinery and industrial equipment (ISIC 38 classification). The distribution of the sample by industry and country is shown in **Tables 3.1** and **Table 3.2** respectively. The total sample size of this study is 558, with the average return rate exceeding 35%. Manufacturers of metal products and machinery represent over 80% of the sample, while manufacturers in China, Germany and the US have the largest company size with over 1000 personnel comparing to the average size of 684 personnel. Among the 17 countries, US manufacturers represent about 21% of the sample and follow by Italy (10.67%), Germany (10.12%) and China (9.75%).

ISIC	Industry	n	Percent
381	Fabricated metal products	180	32.26%
382	Machinery except electrical	145	25.99%
383	Electrical machinery apparatus, appliances and supplies	134	24.01%
384	Automotive and transportation equipment	50	8.96%
385	Measuring and controling equipment	49	8.78%
	Total	**558**	**100.00%**

Table 3.1 Industry distribution of the sample

The research reported in this paper was based on the data from the third round of IMSS survey. A questionnaire was designed by a special team and then data were collected from participating countries. The questionnaire was divided into four sections: (a) strategies, goals, and costs, (b) current manufacturing and integration practices, (c) past and planned

activities in manufacturing, and (d) manufacturing performance measures and indicators. The respondent was generally the production manager, or the general manager. Data collection methods varied from country to country. In some countries, sample selection was at the coordinators' convenience, and others used random sampling. Telephone contact was followed in most of the participating countries, except for the Netherlands. The questionnaires were forwarded to participating companies via mailing, fax or on-site interview. In those countries where English is not used, the questionnaire was translated into local native languages. Participating countries sent their data to the coordinator who forwarded the final database to all research participants.

Country	Sample size	Average size (Number of employees)	% of sample
Argentina	14	281	1.04%
Australia	40	253	2.68%
Belgium	19	381	1.92%
Brazil	35	579	5.37%
China	30	1227	9.75%
Croatia	35	560	5.19%
Denmark	38	397	4.00%
Germany	32	1194	10.12%
Hungary	58	545	8.38%
Ireland	32	377	3.20%
Italy	60	671	10.67%
Netherlands	14	207	0.77%
Norway	51	161	2.18%
Spain	20	664	3.52%
Sweden	19	645	3.25%
United Kingdom	47	546	6.80%
USA	14	5705	21.16%
Total	**558**	**676**	**100.00%**

Table 3.2 Geographic distribution of the sample

3.4.2   Measurement development

Operationalization of research variables in this study was based on the self-developed items derived from section (b) current manufacturing and integration practices, and section (c) past and planned activities in manufacturing, of the IMSS questionnaire and was substantiated by the related studies in literature review. Multiple items were used to

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measure the research constructs. The researchers attempted to examine the items side-by-side with the intention to enhance reliability of the measurement. For example, use of information systems for supplier integration was examined from both supplier's perspective and manufacturer's perspective in order to avoid bias result, and same approach was used when measuring other items. All items were measured by a five point Likert scale with 1 indicating "none" or "not important" and 5 indicating "high" or "very important". On the ground of IDT (Rogers, 1983), JIT implementation model (Buker, 1991) and the related studies in literature review, we theorized that electronic-enabled supply chain integration has positive effect on the relative advantage of lean production which positively influences the ongoing adoption of lean production. Hence, corresponding measurements for lean production adoption, relative advantage of lean production and readiness of electronic-enabled supply chain integration were identified. **Table 3.3** summarized all the constructs with their corresponding variables.

(I)   Measures for the adoption and relative advantage of lean production

Since successful innovation diffusion is about the continuous use of an idea once it is adopted as practice (Rogers, 1983), our study on lean production systems adoption concerns long-term use of supply chain information systems by manufacturers and their supply chain counterparts. In **Figure 3.1**, the dependent variables are associated with the continuous adoption of lean production which was operationalized as manufacturers' intention of use in the long-term and was measured by the extent of using lean for at least three years practice as proposed by Bayou and Korvin (2008).

Manufacturers' intention of investing in lean production is justified by the relative advantage of lean production which concerns two measurements. They are: (1) "perceived usefulness" measured by the level of using lean production in the last three years; and (2) "perceived benefits" measured by economic return which were operationalized as the pay-off of using lean production in the last three years. The two measurements of "use" and "benefits" were adapted from Moore and Benbasat (1991), and Rogers (1983), respectively, while lean production was measured based on Buker (1991)'s JIT implementation model which emphasizes four management philosophies: (1) *restructuring supply strategy* for coping with the agreed efficiency targets by sharing the information of material management, inventory and forecast with suppliers, reducing the number of suppliers and investing in supply chain technologies; (2) *implementing pull production* based demand

driven principle for better addressing customer needs in the downstream supply chain; (3) *process focus and streamlining* for simplifying complex operations; and (4) *empowerment of workforce* for streamlining operations and decision processes. The adoption and relative advantage of lean production was evaluated based on these four philosophies. Basing on Rogers (1983), the benefits of these changes can only be observed if they are used substantially, which substantiate Bayou and Korvin's (2008) argument on extended measurement of lean production. Thus, the three constructs, "perceived usefulness", "perceived benefits" and "lean production adoption" were operationalized into these four dimensions and were measured by a 5-point Likert scale in a three years period.

(II)   Measures for electronic-enabled supply chain integration

The independent variables measure the degree of electronic-enabled supply chain integration. It represents the extent of information systems diffusion in manufacturing supply chain integration in supporting the adoption of lean production as innovation (Rogers, 1983). Based on the literature review, an ERP system is the enabler of organizational integration and an Extranet/EDI system is the enabler of supplier integration. Hence, the variables are operationalized by measuring the extent of using information systems in two aspects, namely: (1) extent of using Extranet/EDI systems in "supplier integration" on the upstream manufacturing supply chain; and (2) extent of using ERP systems in "organization integration" related to production and various management areas.

The variables that measure area (1) include both: (a) extranet/EDI systems invested by manufacturers, and (b) extranet/EDI systems invested by suppliers. Basing on Li (2007), the measures of area (2) were operationalized in five management areas: (a) material management; (b) production planning and control; (c) sales and distribution management; (d) purchasing and supply management; and (e) accounting and finance management. Likewise, all variables of the two constructs were measured by a 5-point Likert scale.

3.5   Data analysis

A two-stage data analysis approach was used to analyze the measurement model and the structural relationships among latent constructs (Anderson and Gerbing, 1988). First, reliability and validity of the constructs were assessed, which included a combination of methods. In the second stage of the analysis, structural equation modeling was used to test

the proposed theoretical model.

Measures	Factor Loading				
	1	2	3	4	5
Electronic-enabled Supply Chain Integration					
1 Supplier Integration (α = 0.818)					
Extranet/EDI for suppliers	0.921				
Extranet/EDI for manufacturers	0.921				
2 Organization Integration (α = 0.897)					
ERP for material management		0.906			
ERP for production planning & control		0.793			
ERP for purchasing and supply management		0.779			
ERP for sales and distribution management		0.893			
ERP for accounting and finance		0.838			
Relative Advantage					
3 Perceived Usefulness (α = 0.773)					
Restructuring Supply strategy			0.719		
Implementing Pull production			0.792		
Obtaining Process focus & streamlinng			0.819		
Empowerment of workforce			0.754		
4 Perceived Benefits (α = 0.687)					
Restructuring Supply strategy				0.671	
Implementing Pull production				0.752	
Obtaining Process focus & streamlinng				0.774	
Empowerment of workforce				0.672	
Adoption of Lean Production					
5 Intention of Use (α = 0.724)					
Restructuring Supply strategy					0.761
Implementing Pull production					0.769
Obtaining Process focus & streamlinng					0.780
Empowerment of workforce					0.642
KMO	0.5	0.858	0.760	0.724	0.736

Table 3.3 Results of factor analysis and reliability analysis

3.5.1 Reliability and validity

Cronbach's alpha model was used to perform reliability analysis and alpha coefficient was generated for each construct. An alpha coefficient is typically considered adequate if it exceeds 0.7 (Cronbach, 1951; Nunnally, 1978, Fornell and Larcker, 1981; Bagozzi and Yi, 1988; Nunnally and Bernstein, 1994; Chen and Pauley, 2004). The constructs with an alpha value of at least 0.6 should be further evaluated for the possibility of improvement (Chen and Pauley, 2004). **Table 3.3** shows that the alpha coefficient of the constructs are in the acceptable range between 0.7 and 0.9, except "*perceived benefit*" which is slightly smaller

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than 0.7, i.e. 0.687. The reason may be in part due to new questions, which were not presented in previous editions of the survey. Therefore, we consider the reliability of this construct is still established.

Exploratory factor analysis (EFA) using principal component analysis method was employed for testing construct validity. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, which ranges between 0 and 1, was used to detect whether or not the data factored well before the factor analysis. As shown in **Table 3.3**, the KMO value ranges between 0.5 and 0.858 which is greater than or equal to the minimum acceptable value of 0.5 (Kaiser, 1974).

Both convergence validity and discriminant validity were examined. Convergent validity represents how well the item measures related to each other in representing a concept (Swafford *et al.*, 2008). The presence of significant factor loadings demonstrates convergent validity (Anderson and Gerbing, 1988). The factor loading of constructs is directly proportional to sample size and the factor loading for sample size larger than or equal to 350 exceeds 0.30 (Hair *et al.* 1998). It is generally acceptable that if the value of factor loading is greater than 0.60 (Gyampah and Salam, 2004; Hong and Zhu, 2006). All factor loadings shown in **Table 3.3** demonstrate desirable convergent validity with value over 0.60.

Correlation and AVE

		AVE	1	2	3	4	5
1	Supplier Integration	0.8482	0.921				
2	Organization Integration	0.7112	0.214**	0.843			
3	Perceived Usefulness	0.5959	0.433**	0.351**	0.772		
4	Perceived Benefits	0.5166	0.343**	0.165**	0.745**	0.719	
5	Intention of Use	0.5478	0.331**	0.246**	0.616**	0.542**	0.740

** p = 0.01

Table 3.4 Correlations and AVE

Discriminant validity occurs when measures of each construct are distinct from one another (Campbell and Fiske, 1959). The model demonstrates discriminant validity if the square root of the average variance extracted (AVE) by each construct exceeds the

corresponding inter-variable correlation (Fornell and Larcker, 1981). AVE is the average squared factor loading. AVE of less than 0.5 indicates that on average, more error remains in the items than variance explained by latent factor structure imposed on the measure (Hair *et al.*, 1998). The overall results in **Table 3.4** show reasonable discriminant validity. Therefore, we conclude that the scales should have sufficient construct reliability and validity. In addition, the values of Pearson's correlation coefficient among the constructs below the diagonal of the matrix are all significant at the p = 0.01 level. We noted that significant correlations exist among all variables which suggest this to be considered in subsequent analysis on testing the hypothesized relationships and model fit.

3.5.2 Fitness of estimation model

The *Structural Equation Modeling* (SEM) method was used to test the proposed theoretical model (Jöreskog and Sörbom, 2003). Six hypotheses were simultaneously tested using SEM. Insignificant paths were deleted from the proposed model if it did not fit well and it was then tested again. A two-step procedure is followed to evaluate the model fitness (Sun *et al.*, 2008): (i) we first examine the significance of path and measurement coefficients; (ii) the whole model fit is then examined by using multiple criteria based on Hu and Bentler (1999).

Hypothesis	Path from	Path to	Path Coefficient	Supported
	Relative Advantage of Lean Production → Adoption of Lean Production (Model 1)			
H1	Perceived Benefits	Adoption of Lean Production	0.417***	Yes
H2a	Perceived Usefulness	Adoption of Lean Production	0.271***	Yes
H2b	Perceived Usefulness	Perceived Benefits	0.838***	Yes
	Electronic-enabled Supply Chain Integration → Relative Advantage of Lean Production (Model 2)			
H3	Supplier Integration	Perceived Usefulness	0.382***	Yes
H4a	Organization Integration	Perceived Usefulness	0.275***	Yes
H4b	Organization Integration	Supplier Integration	0.212***	Yes

*** p<0.001

Table 3.5 Results of estimation structural model

Because χ^2 is sensitive to sample size and, due to our large sample size, an alternative of

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normed Chi-square (χ^2/d.f.) is used to assess the model fit (Hu and Bentler, 1999). In addition, non-normed fit index (NNFI), comparative fit index (CFI) and root mean square error of approximation (RMSEA) were also used. Generally, NNFI value above 0.9, CFI value above 0.9, RMSEA value below 0.05 are regarded as a good fit. RMSEA between 0.05 and 0.08 (Browne and Cudeck, 1993) can be acceptable. For normed chi-square, Carmines and McIver (1981) recommended the value be less than three.

The model was tested with SEM method in the AMOS 16.0 software (Byrne, 2001). **Table 3.5** shows that all the paths are significant with p<0.001 which imply that all hypotheses are significant. The model fit indexes are within acceptable thresholds: χ^2/d.f.=1.448<3, NNFI=0.988>0.9, CFI=0.997>0.9 and RMSEA=0.028<0.05. The results indicate that the goodness of fit of the model is acceptable.

Independent variables	Dependent variables
	Adoption of Lean Production
(Perceived Usefulness, Perceived Benefits)	R^2 = 0.437, F = 112.161 (p < 0.001), n = 292
	Perceived Benefits
(Perceived Usefulness)	R^2 = 0.702, F = 690.221 (p < 0.001), n = 295
	Perceived Usefulness
(Supplier Integration, Organization Integration)	R^2 = 0.267, F = 47.535 (p < 0.001), n = 264
	Supplier Integration
(Organization Integration)	R^2 = 0.045, F = 13.335 (p < 0.001), n = 285

Table 3.6 R^2 and *F*-values of the estimation model

The explanatory power of the model was then tested by evaluating the significance of R^2 (Pedhazur and Schmelkin, 1991). The approach enables the study to obtain the percentage of variance explained by each independent variable separately as well as the significance of the hypothesized relationships. The significance of R^2 was tested with an *F*-test (Allison, 1999; Allen *et al.*, 2009). As summarized in **Table 3.6**, the R^2 values of supplier integration, perceived usefulness, perceived benefits and adoption of lean production were all significant. This implies that the explanatory power of the estimation model is sufficient,

providing further support for the hypotheses.

3.6 Discussion and implications

3.6.1 Electronic-enabled supply chain integration

We theorized that electronic-enabled supply chain integration positively influences the relative advantage of using lean production systems (model 2 in **Table 3.5**). EMSC integration is measured by the extent of information systems being used in relevant supply chain activities which reveals the degree of information systems diffusion. Two aspects of supply chain integration are benefit most from deeper information systems diffusion, i.e. organization integration (internal supply chain) and supplier integration (external supply chain) which highly demand automated information flow at both speed and quality.

Two endogenous functions and associated variables in electronic-enabled supply chain integration were tested. According to the test results, perceived usefulness was found to be significantly influenced by supplier integration (H3: $\beta=0.382$ at $p<0.001$) and organization integration (H4a: $\beta=0.275$ at $p<0.001$) resulting in an $R^2=0.267$. This means that the combined effects of supplier integration and organization integration explained 26% of the variance of perceived usefulness. Supplier integration was also found to be influenced by organization integration (H4b: $\beta=0.212$ at $p<0.001$) and resulting in an $R^2=0.045$. We have further tested the predictability of the function with F-test (Allen *et al.*, 2009) and obtained results significantly greater than the critical value. The arguments are fully supported by the empirical results and we have the following findings.

First, the test results of H3 and H4a suggest that contextualizing EMSC in supply chain integration is important to implement lean production in a supply chain environment. Practically speaking, supply chain activities concerning decision support and transaction processing are readily supported by the information systems for lean production (Bozarth and Handfield, 2008). For example, e-kanban and efficient consumer response (ECR) driven by ERP/EDI systems extend JIT/lean production along the supply chain that force manufacturers and suppliers to work collaboratively toward lean objectives (Waters, 2009). The empirical results imply that implementing lean production in EMSC help improving manufacturers' operation efficiency through the integration of end-to-end supply chain information flow. Both manufacturers and suppliers have to participate and invest in EMSC to make things happen.

Second, the test results of hypothesis H4b indicate that the two integration dimensions supported by EMSC are significantly correlated. With EMSC in place, organization integration has significant positive influence on supplier integration which indirectly influences the perceived usefulness of lean production. With the presence of EMSC, end-to-end e-kanban replenishment signaling system can be implemented with signals traversed between upstream and downstream of the manufacturing supply chain. This helps extending the value stream of lean production systems from manufacturers to suppliers which creates a win-win situation (Womack and Jones, 1996).

3.6.2 Relative advantage of lean production

We theorized that manufacturers' perceived relative advantage of using lean production systems positively influences their long term adoption (model 1 in **Table 3.5**). By the same token, the endogenous functions and associated variables in lean production adoption were tested. First, the adoption of lean production was found to be significantly influenced by perceived benefits (H1: $\beta=0.417$ at $p<0.001$) as well as perceived usefulness (H2a: $\beta=0.271$ at $p<0.001$) resulting in an $R^2=0.437$. This means that the combined effects of perceived benefits and perceived usefulness explained 43.7% of the variance of the adoption. Also, perceived benefits was found to be significantly influenced by perceived usefulness (H2b: $\beta=0.838$ at $p<0.001$) and resulting in an $R^2=0.702$. Our study shows that the empirical results strongly support hypotheses H1, H2a and H2b. Therefore, we have the following findings.

EMSC, as the pipeline of information exchange and enabler of information integration for a manufacturing supply chain, is capable to extend the value stream of lean production such as reducing lead time, inventory and operation costs, beyond the four walls of manufacturers. This information management capability adds values to suppliers who provide manufacturers with parts as well as customers who purchase finished goods from manufacturers (Bozarth and Handfield, 2008). Hypotheses H1 and H2a suggest that this capability causes a positive effect on the perceived relative advantage of lean production which influences the long-term adoption of lean production philosophy.

Last but not the least, the empirical results of hypothesis H2b imply that having job performance improved by adopting lean production systems, would bring economic benefits to manufacturers and reinforce its long-term adoption. Most importantly, the results suggest that the bottom-line of manufacturers might be improved if the

implementation of four proposed lean production principles: (1) restructuring supply strategy; (2) implementing pull production; (3) streamlining manufacturing process; and (4) empowerment of workforce, achieves results.

3.6.3   Implications and related cases

Our model revealed that supplier integration in an EMSC environment has significant positive effect on the relative advantage of lean production systems with the participation of and investment from both suppliers and manufacturers (H3: $\beta=0.382$ at $p<0.001$) which is an important antecedent of lean production systems adoption (H2a: $\beta=0.271$ at $p<0.001$). Hence, manufacturers may restructure their supply strategies such that only those companies who participate and invest in EMSC can become their suppliers. This approach has been adopted by the industry for better supporting sizable operation improvement programmes. Two cases are presented to illustrate how supply strategy can be restructured based on supply chain enabling technology in supporting lean principles:

(1) **Wal-Mart**, an US retailer, strictly required its top 100 suppliers to implement radio frequency identification (RFID) technology on the supplies at pallet level and case level for operation improvement since 2005. This lean initiative essentially realizes the "pull" approach through sending real-time inventory data from individual store to suppliers. Working together, Wal-Mart and its suppliers use the data to improve replenishment with out-of-stocks reduced by 16% by tracking cases of goods with RFID tags carrying Electronic Product Codes (EPCs). In addition, this data enables suppliers to measure the execution of promotions and boost sales which is a benefit to both parties (Roberti, 2004; 2005; 2007).

(2) **Pratt & Whitney (P&W)**, a US manufacturer, engages in the design, manufacture and service of aircraft engines, space propulsion systems and industrial gas turbines. P&W reduced the supply cost at 20% in four years through the implementation of lean principles to its small machined parts supply network. As part of P&W's lean supply strategy, all suppliers have to upgrade their network and software so that they can exchange the information of cost, delivery, quality, master production schedule and surplus equipment as well as other valuable data with P&W promptly which helps establish and reinforce performance expectations. The suppliers were evaluated and scored based on the performance (Emiliani, 2006; P&W, 2009).

With the capability of sharing critical business information and conducting transactions with suppliers in a timely manner over a common platform, the key lean production principles: (a) improving material and information flow; (b) customer pull; and (c) continuous improvement, can be realized by creating lean suppliers (Womack *et al.*, 1991; Womack and Jones, 1996). Moreover, this helps manufacturers not only to extend the values of new practice to their suppliers but also to establish a closer supplier relationship in the long run.

3.7   Limitation of the study and future research

Like most research, there are a few limitations of the study. This study evaluates lean principles and SCM integration from the standpoint of a manufacturing company (the firm in the midstream of EMSC). The constructs are not appropriate for distributors and retailers (the firms at the downstream of EMSC), as each construct includes one or more production centric items. Due to the concept of SCM being complex and involves a network of companies in the effort of producing and delivering a final product, our study does not involve the downstream companies in the manufacturing supply chain. Besides, we should note that the implementation of lean production in a supply chain environment may be influenced by contextual factors, such as firm size, a firm's position in the supply chain, and experience involved in the use of lean in relation to various EMSC systems and technologies. For example, the larger manufacturers usually have more complex organization structure and supply chain networks which normally demand more systematic processes, peoples with relevant experience and comprehensive information systems to be in place for managing works that are becoming more complex and also changes in the transition to a new practice. Future research can study the impact of such factors on the implementation of lean production.

The use of single respondent may generate some measurement inaccuracy. Future research should survey multiple respondents (SCM & logistics, IT and operations managers) from each organization. Hence, the discrepancies of SCM and lean production perception between the groups and the impact of such discrepancies on overall result can be examined. In addition to the time and cost of operation as the important measures of lean success, some lean practitioners propose customer satisfaction as an alternate measure (Plenert, 2007). On this ground, future study can compare customer relationship management (CRM) against supplier integration in the EMSC environment that influences the adoption of lean

production. The empirical results will help integrating manufacturers' upstream suppliers and downstream customers towards lean manufacturing objectives. Also, measures on lean practice in other human aspects such as relationship management can be investigated in the future study so that manufacturers will know if people's capabilities can be improved. This is the value that TPS originally advocated (Sugimori *et al.*, 1977).

3.8   Contributions and conclusions

The study contributes to both theory and practice. First, this study combines Rogers's IDT and Buker's JIT implementation model with the attributes of EMSC integration basing on previous studies, and proposes a new hybrid model to explain lean production adoption in an e-supply chain environment. Second, the attributes of perceived relative advantage of lean production were derived from IDT. The empirical results demonstrate that IDT can explain lean production as management practice besides technology adoption. Lastly, perceived usefulness and perceived benefits had a significant combined effect on lean production adoption with an explanatory power of $R^2=0.437$ in which perceived usefulness was found to be an important antecedent of perceived benefits (H2b: $\beta=0.838$ at p<0.001) with an explanatory power of $R^2=0.702$. Hence, perceived usefulness representing the attributes of job performance enhancement explains the beneficial consequences of adopting lean production as innovative practice, and has the implications of improving manufacturers' anticipated bottom line (Rogers, 1983; Davis, 1989; Moore and Benbasat, 1991). The attributes can be adapted in strategy development for adopting lean production as a sustainable practice.

In conclusion, the study addresses two fundamental questions on the adoption of lean production: (1) "what causes manufacturers to accept lean production systems?", and (2) "how do these factors affect the acceptance of lean production systems?" To answer the questions, a theoretical model was developed to explore various adoption factors of lean production. Two indicative dimensions were identified that influence the adoption, namely, the readiness of EMSC for supply chain integration and the relative advantage of lean production. Six hypotheses were developed for the model and were all proved to be statistically significant. Thus, the continued development of EMSC enabling technology and information systems, e.g. RFID, e-kanban or CRM is expected to motivate and facilitate further theory development and empirical investigation in lean production and manufacturing supply chain integration.

Chapter 4   ADOPTING LEAN PRINCIPLE AS SUSTAINABLE MANUFACTURING STRATEGY IN AN ELECTRONIC-ENABLED SUPPLY CHAIN ENVIRONMENT

The second article was published in the International Journal of Sustainable Economy (So, 2010). It is an extension of the first paper and studies the causal relationship between supplier integration strategy and adopting lean principles in manufacturing firms based on the same empirical data set used in the first publication. The study extends the lean principles further to upstream suppliers based on the work of Lewis (2006) who argued that adopting relevant supply strategy based on lean principles can remove Ohno's (1998) wastes from the system. Supply management is executed on demand driven (i.e. customer pull) supply chains through better coordinating material flow, inventory and production planning (Buker, 1991). Hence, the value stream of lean manufacturing systems can be extended to suppliers and creates mutual benefit. The findings suggest that lean supply strategy aiming at supplier integration can be established by measuring supplier's information management capability and the use of policy-based supplier selection by adopting EMSC-enabled lean manufacturing. The latter offers manufacturers and suppliers with information sharing and e-business functions in supporting speedy and reliable information exchange in the supply chain.

The research suggests four measures to study the supplier integration effect on lean adoption: (1) the suppliers' delivery performance, (2) the suppliers' ability to provide innovation and co-design support, (3) the suppliers' willingness to disclose cost and other information, and (4) the suppliers' historical performance. These four measures concern the essential supplier quality to meet the lean objectives which are used as the supplier selection criteria in the supply strategy. Also, the findings agreed with Roger's (1995) innovation diffusion theory (IDT) that on-going adoption of lean manufacturing as sustainable strategy is a long term commitment based on a structural decision process from understanding, persuading, accepting, and implementation, to confirmation of adoption. The results suggest that supplier-manufacturer collaboration can only be sustainable if supplier integration strategy is developed for properly selecting and developing suitable suppliers capable of supporting lean manufacturing. As a result, manufacturers may restructure their supply strategies such that only those companies that participate and

invest in EMSC can become their suppliers.

Adopting lean principle as sustainable manufacturing strategy in an electronic-enabled supply chain environment

Abstract:

This paper empirically examines the influence of lean supply strategy implemented in electronic-enabled manufacturing supply chains (EMSC) on lean manufacturing adoption in a sustainable manner. Adopting lean manufacturing often not only requires a lengthy period but also involves a prolonged decision process which makes sense to identify the antecedents for improving decision-making. The influential factors including information sharing and use of e-business system in supplier integration together with lean performance based supplier selection were tested with statistical methods based on survey data. It was found that lean manufacturing adoption is positively influenced by all these factors. Moreover, the results revealed that manufacturers may commit ongoing use of lean principle only if it has been adopted as regular practice. Lastly, managerial implications and future research were discussed to alleviate practical concerns in the execution of waste-reducing lean supply strategy and to explore the potential of developing reverse logistics on this platform.

4.1 Introduction

Sustainability constitutes of environmental, social, and economic dimensions in which waste management is one of the major challenges along the three dimensions (United Nations, 2005). Ohno (1988) identified seven kinds of waste that need to be controlled in manufacturing, and they are (1) overproduction, (2) transportation, (3) inventory, (4) motion, (5) defects, (6) over-processing, and (7) waiting. These seven wastes represent the most commonly wasted resources and their associated wasteful manufacturing activities which do not add value or are unproductive, for example, mistakes which require rectification, production of items no one wants so that inventories and remaindered goods pile up, processing steps which are not needed, movement of employees and transport of goods from one place to another without any purpose, groups of people in a downstream activity standing around waiting because an upstream activity has not delivered on time, and good and services which do not meet customer needs (Womack and Jones, 2003). The last activity, that is, not meeting customer needs, represents the eighth waste in manufacturing. These wastes can be primarily classified into two categories, that is, waste in form of resources (raw materials, WIP, etc.) that are transformed in manufacturing and transforming resources such as people, process technology, facilities, etc (Lewis, 2006). Each of these wastes corresponds to some form of *loss* in value such as loss in material, factory, and equipment utilization, time, man-hours and dollars that companies must ultimately pass to their customers which is essentially avoidable (Ruffa, 2008).

As one of the manufacturing best practices, lean principle preaches simplification and elimination of wasteful processes, which is applicable to overly-complex and non-integrated processes that are inefficient and provide little added values. To be a lean enterprise enables manufacturers to improve throughput, reduce costs and wasteful tasks, and deliver shipment with shorter lead times so that *losses* caused by the eight wastes can be avoided. Basing on the longitudinal studies on European manufacturing industry, Bhasin and Burcher (2006) argued that lean manufacturing can help reduce waste by 40%, cut costs by between 15% and 70%, decrease space and inventory requirements by 60%, push productivity up between 15% and 40% whilst cutting process changeovers by 60% which show the potentials of lean as sustainable practice. Besides, it may offer significant competitive advantages to manufacturers as early adopters. Today, manufacturers are dealing with even more complex and longer supply chains than ever (Cooke, 1997;

Rudberg and Olhager, 2003; Simchi-levi *et al.*, 2008). Extending lean principles from manufacturing to supply chain management (SCM) can leverage the supply chain's competitiveness further with increased responsiveness to demand change and reduced operating costs (Oliver *et al.*, 1993; Ryan, 2001). EMSC, a specific kind of e-supply chain in manufacturing, offer lean manufacturers an environment with speedy data communication and reliable information management which may influence the continuous development and long-term adoption of lean principles in manufacturing (Li, 2007; Rudberg and Olhager, 2003).

Lewis (2006) argued that lean manufacturing reduces the level of input resources in the system for a given level of output which is achieved by preventing or removing the eight wastes from the system along the three sustainability dimensions through adopting relevant supply management strategy which brings manufacturers sustainable competitive advantage. As supply management is highly related to demand driven (pull) supply chains through better coordinating material flow, inventory and production planning, *adopting lean manufacturing in EMSC oriented to waste-reducing lean supply strategy can be a sustainable manufacturing best practice*. In a recent study on sustainable manufacturing best practice conducted with 230 manufacturers in North America, Europe and Asia, 78% of the respondents included waste reduction into their corporate sustainability agenda, 77% of the respondents used overall equipment effectiveness (i.e. availability, quality and performance of transforming resources in manufacturing) as KPI to measure the outcomes of sustainability programmes and 57% of the respondents adopt SCM as technological enabler (Shah and Littlefield, 2009). The proposed conceptual framework is consistent with the international trend of sustainable manufacturing.

The goal of this study is to provide manufacturers with insights on implementing and adopting lean manufacturing as a sustainable practice in an EMSC environment *through the influence of lean supply strategy*. The influence of lean supply strategy on the long-term use of lean principle was examined by integrating various supply and production related activities in manufacturing companies as a sustainable manufacturing practice with the aim to address two basic questions – (1) "what causes manufacturers to adopt lean manufacturing as a sustainable practice?", and (2) "how is the lean manufacturing adoption affected in the decision process?". In the forthcoming sections, we present supportive literature, establish a theoretical model and draw associated hypotheses, empirically test the model based on the survey data from 558 manufacturing firms in 17 countries,

demonstrate the potential of lean manufacturing and propose aspects that lead to better implement the practice towards sustainability.

4.2 Theoretical background

4.2.1 Lean manufacturing in an EMSC environment

Bayou and Korvin (2008) simply defined, "To be lean is to cut fat" which pinpointed accurately the purpose of this contemporary management philosophy. Lean thinking start-off in manufacturing representing the meaning of "manufacturing without waste", and waste can be anything other than the minimum amount of equipment, materials, parts, and working time that are essential to production (Taj, 2008). Creese (2000) defines lean differently as "a manufacturing philosophy to shorten lead times and reduce costs by redirecting waste and improving employee performance, skills and satisfaction". Lean manufacturing is originated in Toyota with names "Toyota production system (TPS)" or "Just-in-time (JIT)" manufacturing beginning back in 1960s (Bruun and Mefford, 2004; Reichhart and Holweg, 2007; Taj, 2008; Wu, 2003). Lean manufacturing is an approach including an integrated set of activities designed to achieve high-volume flexible production comparable to mass production but using minimal inventories of raw materials (Hines, 1996; Wang, 2008; Womack *et al.*, 1991).
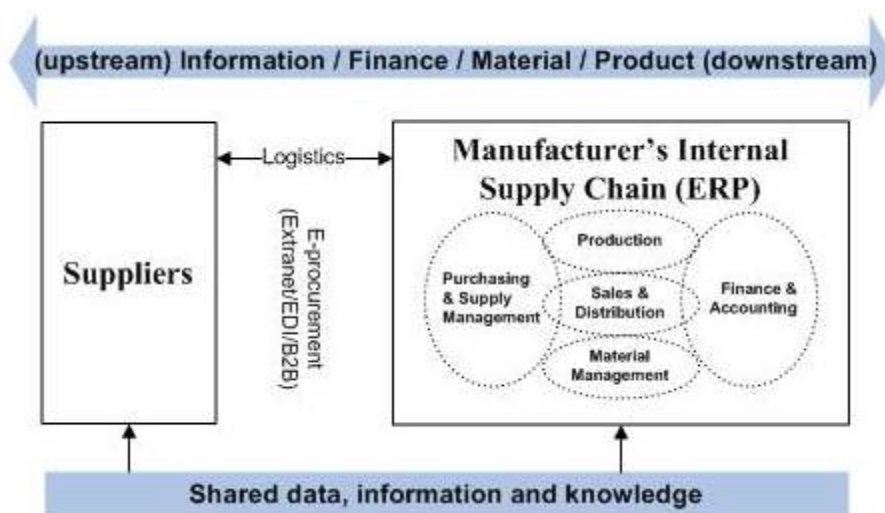

Figure 4.1 Upstream of a typical EMSC (Adapted from Li, 2007)

Lean manufacturing concerns not only with internal manufacturing processes, but also with the operation of the entire supply chain (Oliver *et al.*, 1993). According to Li (2007), a manufacturing supply chain in an e-Business environment comprises (1) internal supply chain which includes various production management and support functions, and (2) upstream supplier network in part of the external supply chain. Having conducted a global study on lean operation with 12 first tier autocomponent suppliers, Ryan (2001) argues that employing supply chain information systems might be an effective method that helps to reduce increasing costs of the ever complex supply chain and enhance buyer-supplier relationships through managing information and communication on a real-time basis. **Figure 4.1** showed the upstream of a typical EMSC with the illustration of suppliers and manufacturers relationships on information management.

4.2.2 Implementing lean as sustainable manufacturing strategy

Lean manufacturing aims to eliminate waste and improve production in a continuous approach such as having only the required inventory when needed, reduction of lead times by reducing setup times, queue lengths, and lot sizes such that these activities are accomplished at minimum cost, and it encompasses the successful execution of all manufacturing activities required to produce a final product, from design, engineering to delivery, and includes all stages of conversion from raw material onward (Cox and Blackstone, 2002). Adopting lean manufacturing is a systematic innovation because it requires interrelated changes in all these activities which influence not only entire enterprise but also the supply chains and bring radical change with added value to business (Chesbrough and Teece, 1998). Buker (1991) established a structural JIT implementation approach and proposed three focus areas to systematically adopt JIT in production:

(a) *Systems Management* addresses the effective distribution of parts and materials and proper use of limited resources which may involve restructuring supply strategy such as forming partnership or network with suppliers and establishing pull production systems such that parts and materials can be produced on demand with very short lead times,

(b) *Technology Management* involves improvement on existing manufacturing processes through streamlining, reorganizing or restructuring the layout and set-up, e.g. using cellular layout, so that waste can be reduced and response time can be minimized,

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(c) *People Management* focuses on the development of human capitals to support continuous improvement objective in JIT through creating proper work environment for employees from the president to the hourly workers towards this objective. This includes empowerment and training of workforce or establishing autonomous team.
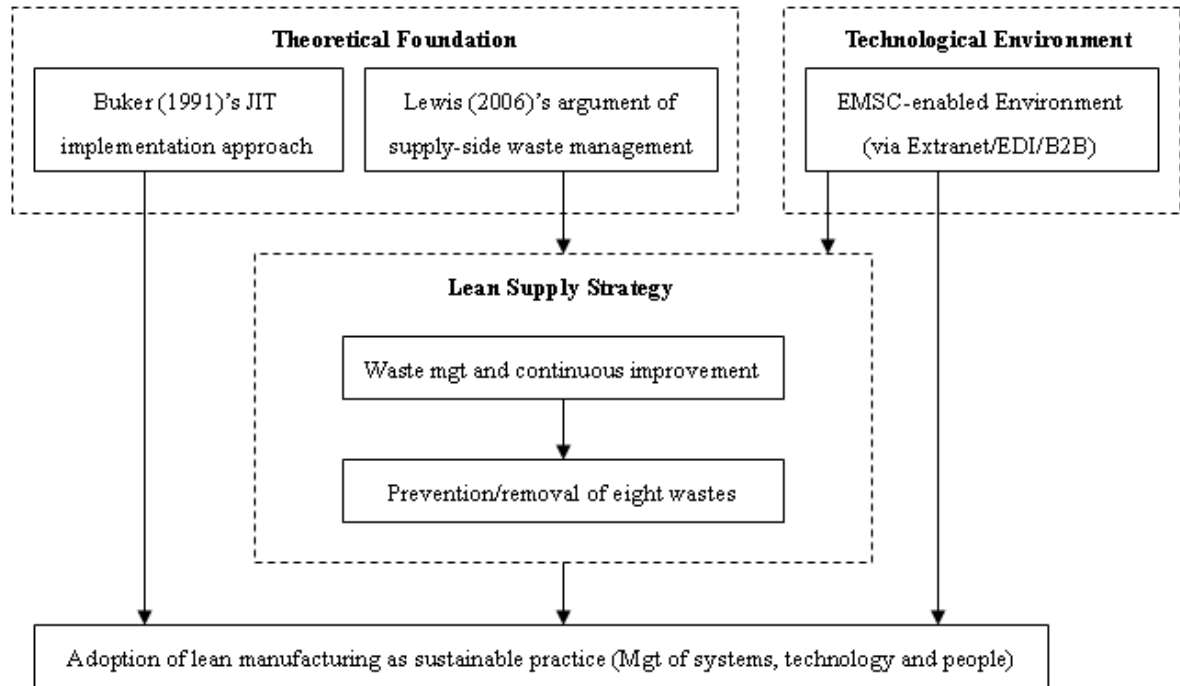

Figure 4.2 Framework of adopting sustainable lean manufacturing

Considering the ability to do more with less, JIT manufacturing is referred as lean manufacturing (Bozarth and Handfield, 2008). Grounded on Lewis (2006)'s argument of supply-side waste elimination and Buker (1991)'s JIT implementation approach, a framework is depicted in **Figure 4.2** to illustrate the relationship between lean supply strategy and the adoption of lean manufacturing as sustainable practice in an EMSC environment, in which continuous improvement of manufacturing operations that help eliminate waste was set-out to be the implementation objective.

4.2.3 Decision process of adopting lean manufacturing

Rogers (1995) emphasized that getting new idea adopted, even when it has obvious advantages, is often very difficult which may normally take quite a lengthy period and may fail in the process of adoption. Implementing lean principles in production brings radical changes to not only the manufacturing operations, but also other areas such as supplier coordination and selection as well as implementing associated information systems in various business units and even reengineering the day-today works of all staff members in the company. The profound impact may lead manufacturers seek reinforcement of their adoption decision already made, as previous decision may be reversed if the management exposed to conflicting messages about lean manufacturing. In order to support manufacturers making appropriate decision throughout the entire decision process, a decision model for adopting lean manufacturing as sustainable practice to the companies in an EMSC environment is proposed based on the innovation diffusions theory (IDT) (Rogers, 1995).
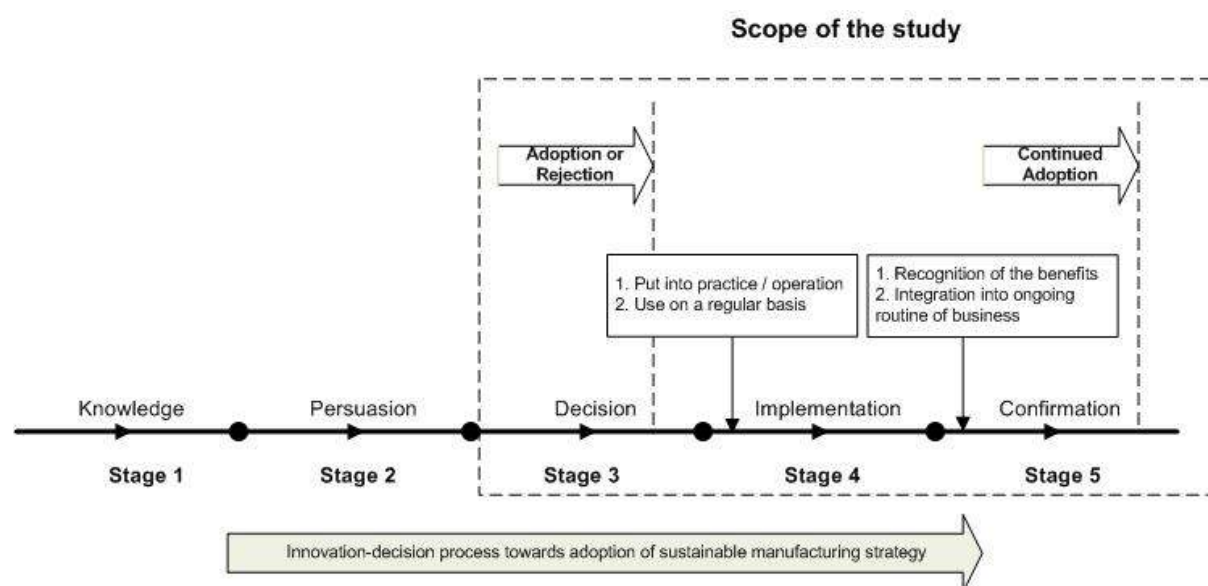

Figure 4.3 Innovation-decision process (adapted from Rogers, 1995)

As depicted in **Figure 4.3**, the decision model has five stages: (1) *knowledge* concerns the understanding of how lean manufacturing principle works, (2) *persuasion* is related to the perceived characteristics of lean manufacturing that lead to the use, (3) *decision* leads to

adopt or reject lean manufacturing, (4) *implementation* involves operational and organizational issues that will be faced when putting new idea to use, and (5) *confirmation* occurs when decision-maker recognizes the benefits of lean manufacturing and integrates as ongoing practice, that is, *adoption*. The decision process before stage 3 (decision) is related to the readiness of end-users and their perceived values of lean manufacturing. Stage 4 (implementation) and onward concern organizational readiness if lean manufacturing was put to day-to-day use in business. In this research, the post-adoption phenomena on the regular use of lean principle in manufacturing that may lead to its ongoing adoption in long run with the aim to be the sustainable manufacturing strategy in an EMSC environment was evaluated based on the stages 4 and 5 characteristics theorized in the IDT (Rogers, 1995).
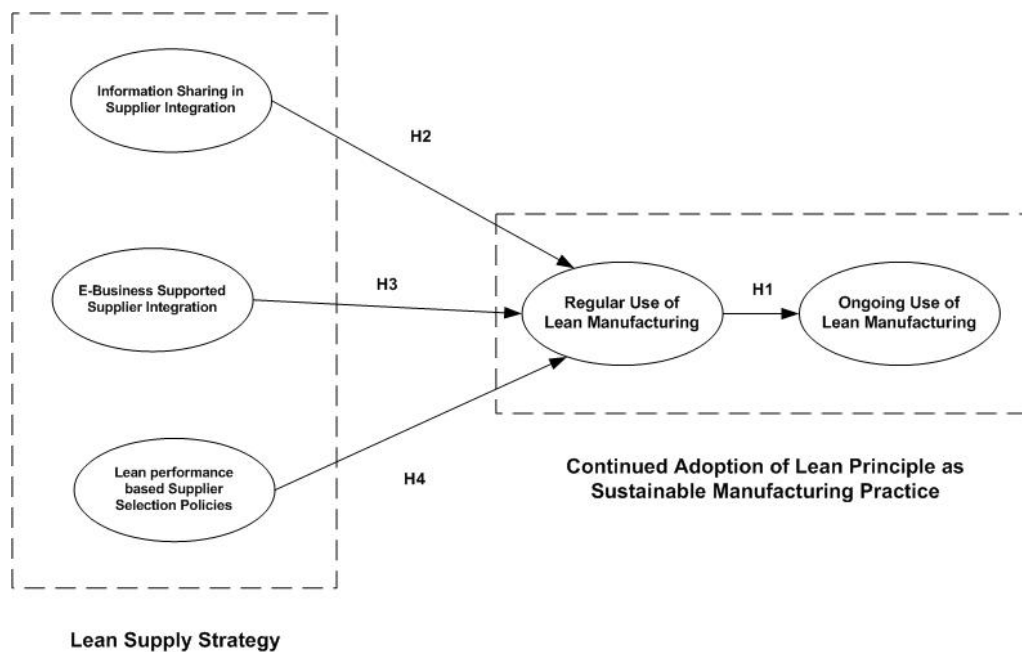

Figure 4.4 Research model

4.3   Research model and hypotheses development

The research model is depicted in **Figure 4.4** and is framed according to the post-adoption characteristics of the innovation-decision process theorized in Rogers' IDT (Rogers, 1995) in which manufacturers have adopted lean manufacturing as regular practice (Stage 4 of

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Figure 4.3) and is tested against the influence on its continued adoption through the integration with daily business routines as an ongoing practice (Stage 5 of **Figure 4.3**). Specifically, we study the effect of adopting lean supply strategy on the continued adoption of lean principle as sustainable manufacturing strategy in an EMSC environment based on the concept depicted in **Figure 4.2**.

Eight manufacturing wastes	Lean supply management approach
Over-production	1. Communicate/share the information of production planning decisions and demand forecast with upstream suppliers, e.g. pull production 2. Share information with suppliers by electronic mean e.g. EDI/ERP, e-procurement systems, and/or B2B systems
Transportation	1. Evaluate the delivery performance of suppliers with the market's benchmark aiming to improve delivery lead-time and inventory holding time 2. Select suppliers based on historical performance
Inventory	1. Communicate and share the actual inventory information with the upstream suppliers through electronic mean. 2. Establish closer supplier relationship with collaboration approach, e.g. VMI/CFPR with relevant IT/information systems, e.g. EDI/B2B systems
Motion	1. Streamline operations through redesigning processes and workflow 2. Improve operation efficiency by using relevant IT and application systems through adopting EDI/ERP, e-procurement systems, and/or B2B systems
Defects	1. Select suppliers based on delivery performance 2. Select suppliers based on historical performance
Over-processing	1. Streamline operations through redesigning process and workflow 2. Improve operations with relevant IT and application systems, e.g. EDI/ERP, e-procurement systems, and/or B2B systems
Waiting	1. Improve communication/information sharing for better coordination of activities from upstream to downstream supply chain with relevant IT and application systems 2. Select suppliers based on historical performance
Customer needs	1. Select suppliers based on the capability of providing innovation and co-design of products in meeting customer needs 2. Select suppliers based on historical performance

Table 4.1 Elimination of eight wastes with lean supply

We measured both the regular use and ongoing use of lean manufacturing practice each in a three-year period (totally six years), congruent with our definition. Based on the model, the decision to continue adopting or not adopting lean manufacturing as ongoing practice is directly affected by the extent of its regular use in the company which is positively influenced by lean supply strategy constituting of the adoption factors, (1) the degree of integration with suppliers in the aspect of using e-business system and information sharing and (2) the extent of using lean performance based supplier selection. Aiming to improve supply-side waste management, **Table 4.1** proposed how the eight wastes are managed

with lean supply strategy. On this ground, the associated hypotheses were developed in the following sections.

4.3.1 Lean manufacturing as sustainable practice

Rogers (1995) identified "relative advantage" in IDT as a primary factor affecting the adoption of innovation where measurements like economic benefit can be used for comparing the advantage of new practice with previous one used. Moore and Benbasat (1991) included "perceived usefulness" which was carried from the studies of technology acceptance model (TAM) with the belief of innovative ideas could enhance job performance (Davis, 1989; Davis *et al.*, 1989). Lean manufacturing must fulfill its intended purpose of better than the precursors after it is adopted and used (Creese, 2000; Moore and Benbasat, 1991; Rogers, 1995). Among the three focus areas, Buker (1991)'s JIT implementation approach emphasizes four management philosophies: (a) *restructuring supply strategy* to cope with agreed efficiency targets by sharing the information of material management, inventory and forecast with suppliers, reducing the number of suppliers and investing in supply chain technologies and IT infrastructure; (b) *implementing pull production* based demand driven principle in order to better address customer needs in the downstream supply chain; (c) *process focus and streamlining* with the aim to simplify overly complex operations; and (d) *empowerment of workforce* for streamlining operation and decision processes. The benefits of these changes can not be observed only if they are put into practice and used regularly in long run.

Manufactures will not commit to use lean manufacturing as ongoing practice unless net positive benefits are observed. By adopting lean manufacturing regularly, improvement would attribute to the job performance of manufacturing workforces and cost structures through reducing waste so that manufacturers' overall productivity can be increased (Creese, 2000; Taj, 2008; Womack *et al.*, 1991), which leads to improved economic benefits by comparing to the precursors (Rogers, 1995; Moore and Benbasat, 1991). Based on the innovation decision process theorized in the IDT, lean manufacturing has to be used consistently until net benefits observed so that decision-makers can be convinced to commit continued adopting it in long run (Rogers, 1995). Hence, we hypothesized H1 as follows:

H1: Regular use of lean manufacturing practice leads to its ongoing adoption as sustainable practice

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4.3.2 Lean supply strategy

(I) Supplier integration

Supplier integration is an area of interest in the context of e-business technologies. This focus is motivated by the fact that manufacturing firms typically spend fifty-five percent of earned revenue on purchased products and services (Bozarth and Handfield, 2008). Guimaraes *et al*. (2002) empirically examine the critical factors that account for the performance of supplier networks. Their theoretical framework hypothesized that supplier network performance is positively influenced by the effectiveness of information technology used and the depth of supplier integration which showed significant positive relationship. More recently, Cagliano *et al.* (2006) conducted a study on lean manufacturing practice adoption in 425 manufacturing firms. The results showed that lean manufacturing practice adoption has a strong association with the integration of information flows with external suppliers. In fact, supplier integration is a major step in the lean manufacturing implementation strategy used by many companies (Black, 2007). In addition, Bozarth and Handfield (2008) highlighted that over 65% of purchasing documents (e.g. purchase orders, amendments, shipping notices and delivery schedules) are going to be exchanged in form of electronic means with the emergence of the Internet. EMSC can be a common platform that provides centralized database as well as information hub for sharing of and controlling the flow of information, among not only manufacturers' internal processes but also their supply chain counterparts in supporting the lean production practice. As supply chain infrastructure connecting the business of manufacturers with trading partners, EMSC enhances information management of both manufacturers and suppliers by reducing wasteful processes and enhancing efficiency which essentially help improve the performance of manufacturers in the aspect of supplier integration. This leads to the following hypotheses:

H2: Information sharing in supplier integration has direct positive influence on regular use of lean manufacturing towards sustainable practice

H3: E-business supported supplier integration has direct positive influence on regular use of lean manufacturing towards sustainable practice

(II) Performance-based supplier selection

The success of lean manufacturing implementation demands high degree of integration of manufacturers with their suppliers through establishing proper supplier selection policies by evaluating metrics like performance, technical competences and supply chain infrastructure capabilities (Bozarth and Handfield, 2008). Basing on Monczka *et al.* (2005), Bozarth and Handfield (2008) argued that suppliers' design and technical expertise can help manufacturers deal with enormous challenges by innovating rapidly and continuously upgrading performance in their markets. Besides, Bashin and Burcher (2006) argued that manufacturers grow profits through cost cutting is not likely to be sustainable and must be balanced with sales growth, innovation, new product development and process improvement where supplier collaboration plays an important role in achieving this goal. On the other hand, Cagliano *et al.* (2006)'s study showed that the adoption of lean manufacturing practices has a strong association with the integration of information flows between manufacturers and suppliers. Basing on their study, ERP systems as part of the EMSC enable the integration of information flow among various supply chain processes which help improve manufacturers' workforce performance through the adoption of lean manufacturing. Besides, the results of their study also showed that lean manufacturing has a strong association with the integration of physical flows of material, inventory and parts among the supply chain counterparts. Grounded on the works by Bozarth and Handfield (2008) and Cagliano *et al.* (2006), the conditions of supplier-manufacturer collaboration that influence lean manufacturing adoption may include delivery and historical performance of suppliers as well as their ability to disclose and share sensitive business information like cost and design data to help manufacturers enhance product innovation and improve operations. These can be used as the measurement criteria for developing supply selection policies for lean manufacturers. Hence, we hypothesize H4 as:

H4: Adopting lean performance-based supplier selection policies has direct positive influence on regular use of lean manufacturing towards sustainable practice

The preceding hypotheses were empirically tested and the results were presented in section 4.5 and discussed in section 4.6. Section 4.4 provides the details of research methodology.

4.4 Methodology

4.4.1 Data collection and sample profiles

The data sample for this research was derived from the International Manufacturing Strategy Survey (IMSS) (Lindberg *et al.*, 1998). The project was initiated by London Business School and Charlmes University of Technology in 1992. IMSS is an international research network consisting of 20 countries and 600 companies around the world, including developed countries, that is, USA, Japan, British, Germany, and developing countries, that is, China, Argentina, Mexico. The participating companies are in the metal products, machinery and equipment industry, i.e. the international Standard Industry Classification (ISIC) 38. The research reported in this paper was based on the data from the third round of IMSS survey.

Country	Sample size	Average size (Number of employees)
Argentina	14	281
Australia	40	253
Belgium	19	381
Brazil	35	579
China	30	1227
Croatia	35	560
Denmark	38	397
Germany	32	1194
Hungary	58	545
Ireland	32	377
Italy	60	671
Netherlands	14	207
Norway	51	161
Spain	20	664
Sweden	19	645
United Kingdom	47	546
USA	14	5705
Total	**558**	**676**

Table 4.2 Sample profiles

Questionnaire was designed with the purpose to reveal the multi-facet of manufacturing strategy and practice. Data was collected from participating countries. Data collection

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method was random sampling and phone contact was followed. The questionnaires were forwarded to participating companies via mailing, fax or on-site interview. In those countries where English is not used, the questionnaire was translated into local native languages. Participating countries sent their data to the research coordinator who forwarded the final database to all participants. The total sample size in this study is 558, with the average return rate exceeding 35%. The sample profiles for 17 participating countries are presented in **Table 4.2**.

4.4.2   Measurement characteristics

Operationalization of research variables in this study is based on the self-developed items derived from the IMSS questionnaire and is substantiated by the related studies in literature review. Multiple items are used to measure the research constructs. The researchers attempted to examine the items side-by-side with the intention to enhance reliability of the measurement. For example, use of E-business systems for supplier integration is examined from both supplier's perspective and manufacturer's perspective in order to avoid bias results, and same approach was used when measuring other items. All items are measured by a five point Likert scale with 1 indicating "none" or "not important" and 5 indicating "high" or "very important". Corresponding measurements for lean manufacturing practice adoption and lean supply strategy in an electronic-enabled supply chain environment are identified. **Table 4.3** summarizes all the constructs with their corresponding variables, while the questionnaire is listed in **Appendix A**.

(I)   Measures for lean manufacturing adoption

Since successful diffusion of innovation is about the continuous use of an idea once it is adopted as practice (Rogers, 1995), our study on the adoption of lean manufacturing practice concerns long-term use of lean manufacturing and its associated investment by manufacturers and their supply chain counterparts which are measured by the extent of using lean for at least three years as proposed by Bayou and Korvin (2008). In **Figure 4.4**, the dependent variables are associated with the continued adoption of lean manufacturing and justified by manufacturers' long-term commitment of using lean manufacturing which concern two measurements. They are (1) "regular use" measured by the level of using lean manufacturing in the last three years, and (2) "ongoing use" measured by the level of using lean manufacturing in the future three years. Basing on Buker (1991)'s approach of JIT

implementation, we evaluated continued lean manufacturing adoption through using (1) restructuring supply strategy, (2) implementing pull production, (3) streamlining manufacturing process, and (4) workforce empowerment.

(II)   Measures for lean supply strategy implementation

The independent variables measure *the degree of supplier integration* and *the extent of use of lean performance-based supplier selection policies*. The degree of supplier integration reflects the extent of adopting lean principle in supplier coordination and management, which are operationalized by measuring the degree of information management adoption in two main aspects, namely (1) extent of sharing business information related to production and various management areas with suppliers, and (2) extent of using e-business systems for exchanging above business information on the upstream manufacturing supply chain. The variables that measure area (1) include sharing information in inventory and demand forecast and production planning decisions. On the other hand, area (2) is operationalized in the extent of investing in E-business technologies such as extranet, EDI and B2B exchange platform by measuring both suppliers and manufacturers, in order to reflect the status of supplier collaboration contributed by both parties. Basing on the literature review, the extent of use of lean performance-based supplier selection policies is measured by assessing suppliers in the dimension of: (1) delivery performance, (2) ability to provide innovation and co-design, (3) willingness to disclose cost, and (4) historical performance.

4.5   Data analysis

4.5.1   Assessment of reliability and validity

Cronbach's alpha model was used to perform reliability analysis and alpha coefficient was generated for each construct. An alpha coefficient is typically considered adequate if it exceeds 0.7 (Bagozzi and Yi, 1988; Chen and Paulraj, 2004; Cronbach, 1951; Fornell and Larcker, 1981; Nunnally, 1978; Nunnally and Bernstein, 1994). The constructs with an alpha value of at least 0.6 remained acceptable but should seek for further improvement (Chen and Paulraj, 2004). **Table 4.3** shows that the alpha coefficients of the constructs are in the acceptable range between 0.6 and 0.9. The reason may be due to new questions, which were not presented in previous editions of the survey. Therefore, we consider the

reliability of this construct is still established.

Measures	Factor Loading				
	1	2	3	4	5
Lean Supply Startegy					
1 E-Business Supported in Supplier Integration (α = 0.818)					
Extranet/EDI/B2B for suppliers	0.921				
Extranet/EDI/B2B for manufacturers	0.921				
2 Information Sharing in Supplier Integration (α = 0.689)					
Share information about the inventory level with suppliers		0.873			
share information about production planning decisions and demand forecast with suppliers		0.873			
3 Lean Performance Based Supplier Selection Policies (α = 0.602)					
Select supplier based on delivery performance			0.654		
Select supplier based on ability to provide innovation and co-design			0.668		
Select supplier based on willingness to disclose cost			0.742		
Select supplier based on historical performance			0.646		
Continued Adoption of Lean Principle as Sustainable Manufacturing Practice					
4 Regular Use of Lean Manufacturing Practice (α = 0.773)					
Restructuring Supply strategy				0.719	
Implementing Pull production				0.792	
Obtaining Process focus & streamlinng				0.819	
Empowerment of workforce				0.754	
5 Ongoing Use of Lean Manufacturing Practice (α = 0.724)					
Restructuring Supply strategy					0.761
Implementing Pull production					0.769
Obtaining Process focus & streamlinng					0.780
Empowerment of workforce					0.642
KMO	0.5	0.5	0.664	0.760	0.736

Table 4.3 Results of factor analysis and reliability analysis

Factor analysis was employed for testing construct validity. Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, which ranges between 0 and 1, was first used to detect if the data factored well before the factor analysis. According to **Table 4.3**, the KMO value ranges between 0.5 and 0.76 which is greater than or equal to the minimum acceptable value of 0.5 (Kaiser, 1974). Convergence validity and discriminant validity were both examined. Convergent validity represents how well the item measures related to each other in representing a concept (Swafford *et al.*, 2008). The presence of significant factor loadings demonstrates convergent validity (Anderson and Gerbing, 1988). The factor loading of constructs is directly proportional to sample size and the factor loading for sample size larger than or equal to 350 exceeds 0.30 (Hair *et al.,* 1998). It is generally

acceptable that if the value of factor loading is greater than 0.6 (Gyampah and Salam, 2004; Hong and Zhu, 2006). All factor loadings presented in **Table 4.3** demonstrate desirable convergent validity with value over 0.6.

Discriminant validity occurs when measures of each construct are distinct from one another (Campbell and Fiske, 1959). The model demonstrates discriminant validity if the square root of the average variance extracted (AVE) by each construct exceeds the corresponding inter-variable correlation (Fornell and Larcker, 1981). The diagonal in **Table 4.4** was replaced with the square root of the AVE of corresponding constructs, and the overall results show reasonable discriminant validity. Therefore, we conclude that the scales should have sufficient construct reliability and validity. In addition, the values of Pearson's correlation coefficient among the constructs below the diagonal of the matrix are all significant at the $p=0.01$ level. We noted that significant correlations exist among all variables which suggesting this to be considered in subsequent analysis on testing the hypothesized relationships and model fit. Lastly, the detail descriptions of these statistical methods are given in **Table B1** of **Appendix B**.

Correlation and AVE

		AVE	1	2	3	4	5
1	Lean Performance Based Supplier Selection Policies	0.460	0.678				
2	Information Sharing in Supplier Integration	0.762	0.310**	0.823			
3	E-Business Supported Supplier Integration	0.848	0.274**	0.268**	0.921		
4	Regular Use of Lean Manufacturing Practice	0.596	0.223**	0.392**	0.433**	0.772	
5	Ongoing Use of Lean Manufacturing Practice	0.548	0.198**	0.285**	0.331**	0.616**	0.740

** $p = 0.01$

Table 4.4 Correlations and AVE

4.5.2 Assessment of estimation model

The estimation model showed in **Figure 4.4** was tested with multiple regression analysis in the SPSS 17.0 software, while the resulting regression weights of all the paths are shown in **Table 4.5**. The approach enables the study to obtain the explanatory power of each independent variable separately as well as the significance of the hypothesized relationships for determining the fitness of the proposed conceptual model through evaluating the significance of multiple correlation coefficients and the beta values

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(Pedhazur and Schmelkin, 1991). Grounded on adequate samples and significant correlation among the constructs of interest, the following casual relationships were evaluated with multiple regression analysis:

(a) Regular use of lean manufacturing practice has positive effect on its continued adoption in long run (Model 1 in **Table 4.5**),

(b) EMSC-enabled supplier integration (supported by information sharing and E-business systems) and lean performance based supplier selection policies have positive effect on the regular use of lean manufacturing practice (Model 2 in **Table 4.5**).

Independent variables	Dependent variables			
	Ongoing Use of Lean Manufacturing Practice (Model1)			
	$R^2 = 0.380$, F = 278.061 (p < 0.001), n = 456			
	B	Beta	t	p
Regular Use of Lean Manufacturing Practice	0.624	0.616	16.675	< 0.001
	Regular Use of Lean Manufacturing Practice (Model 2)			
	$R^2 = 0.275$, F = 32.317 (p < 0.01), n = 259			
	B	Beta	t	p
E-Business Supported Supplier Integration	0.312	0.314	5.520	< 0.01
Information Sharing in Supplier Integration	0.242	0.244	4.286	< 0.01
Lean Performance Based Supplier Selection Policies	0.146	0.157	2.724	< 0.01

Table 4.5 R^2 and *F*-values of the estimation model

According Allison (1999) and Allen *et al.* (2009), the results of multiple regression analysis were evaluated in two steps, (1) how good the predictions were, and (2) how good the coefficient estimates were. In step one, the goodness of predictions was assessed by testing the significance of R^2, that is, the multiple correlation coefficient, representing the degree of reduction in the prediction errors (Allen *et al.*, 2009). Allison (1999) noted that the R^2 value of 0.28 is acceptable which implies that the results are initially desirable. We further conducted an *F*-test to assess the significance of these R^2. The results in **Table 4.5** show that all R^2 are significant at p<0.001 for model 1 and p<0.01 for model 2. Also, this implies that the explanatory power of the estimation model is sufficient. In step two, we tested the significance of the beta weights for each predictor variables with t-test for

evaluating the goodness of the coefficient estimates (Allen *et al.*, 2009). The results show that H1 is significant at p<0.001 while H2, H3 and H4 are significant at p<0.01, providing further support for the hypothesized relationships. Hence, we may conclude that the proposed model is acceptable and all the four hypotheses are significant. Finally, the detail descriptions of these statistical methods are given in **Table B2** of **Appendix B**.

4.6   Results and discussion

4.6.1   Adopting lean principle as sustainable manufacturing practice

In model 1, it is theorized that regular use of lean manufacturing practice has positive influence on its ongoing use in long run. The results of multiple regression analysis showed in **Table 4.5** significantly support the hypotheses, H1 (β=0.616, p<0.001) with good explanatory power of the model (R^2=0.380). Furthermore, the results summarized in **Table 4.3** and **Table 4.4** indicated that the two key constructs exhibit good reliability and validity. This implies that, based on the Buker (1991)'s JIT implementation model, lean manufacturing needs to be adopted in regular use before accepting in long run and demonstrates improvements in various areas of manufacturing operations including: (1) supply management, (2) production management, (3) process optimization, and (4) workforce improvement. The argument is supported by a number of studies on new technological practice adoption. For example, Davis *et al.* (1989) argued that organizational performance cannot be improved if the new practice is not used substantially. Moreover, Yi and Davis (2001) noted that organizations will not be benefited from new practice that was originally designed to improve performance unless users are able to use them. Thus, manufacturers can only be benefited from lean manufacturing only if it is useful and add values through extensive use in the company regularly, which implies that manufacturers may commit ongoing use of lean principle only if it has been used as regular practice.

4.6.2   The influence of lean supply strategy

In model 2, it is theorized that EMSC-enabled lean supply strategy has positive effect on the regular use of lean manufacturing practice. The importance of EMSC is that it offers the support of information sharing and E-business systems as the platform to enable information exchange among various supply chain participants, that is, manufacturer and supplier integration in our study. Likewise, the results summarized in **Table 4.3-4.5**

showed that the model possesses good explanatory power to support the hypothesized relationships with the underlying constructs demonstrating acceptable reliability and validity. Grounded on previous studies of lean manufacturing (Black, 2007; Cagliano *et al.*, 2006) and supply management (Bozarth and Handfield, 2008; Guimaraes *et al.*, 2002), four dimensions to evaluate the effect of lean supply strategy are proposed, (1) suppliers' delivery performance, (2) suppliers' ability to provide innovation and co-design support, (3) suppliers' willingness to disclose cost and other information, and (4) suppliers' historical performance. Measure (2) and measure (3) are related to hypotheses H2 ($\beta=0.244$, $p<0.01$) and H3 ($\beta=0.314$, $p<0.01$) that concern information sharing and its underlying supporting system infrastructure (practice). Whilst, measure (1) and measure (4) are related to hypothesis H4 ($\beta=0.157$, $p<0.01$) that concerns supplier selection policies (pre-implementing). All the results are acceptable, in which H4 is related to the quality of suppliers that may affect their performance to fulfill the lean requirements for collaborating with manufacturers. Hence, manufacturers should carefully pick the supplier selection criteria. Bozarth and Handfield (2008) proposed using weighted preference scores to realize the concept of supplier selection:

$$\text{Preference}_{(\text{Supplier})} = \text{Preference}_{(\text{Supplier, Delivery performance})} * \text{Priority}_{(\text{Delivery performance})} +$$
$$\text{Preference}_{(\text{Supplier, Historical performance})} * \text{Priority}_{(\text{Historical performance})}$$
$$+ \dots$$

Comparing and contrasting the resulting scores of each supplier forms the critical part of implementing lean supply strategy. The results imply that having process view on executing lean supply strategy (pre-implementation and practice) is important. Furthermore, supplier integration based on mutual trust (sharing planning and operation data with both suppliers and manufacturers investing in the infrastructure) is also crucial to the adoption of lean principle as sustainable manufacturing practice along the EMSC.

4.7 Managerial implications

The model revealed that implementing lean supply strategy in an EMSC environment has direct positive effect on the long-term use of lean manufacturing as sustainable practice with the participation of and investment from both suppliers and manufacturers. Hence, manufacturers may restructure their supply policies such that only those companies who are willing to participate and invest in lean manufacturing and associated supply chain

infrastructure (EMSC) can become their suppliers. Similar approach has been adopted by the industry for better supporting sizable operation improvement. For example, Microsoft, Inc. outsourced the manufacture of Xbox to Flextronics, a manufacturer based in Taiwan, based on suppliers' capability of managing its entire supply chain (from supplier networks to internal manufacturing operations by using lean manufacturing practice, for example, collocation, information sharing, IT capabilities, JIT inventory systems and most importantly its historical performance) (Hill, 2006). This helps companies not only to share the values of lean practices with suppliers but also to establish a closer supplier relationship in long run. In addition, the performance of eliminating eight manufacturing wastes depends heavily on the quality of EMSC systems. For example, Lee *et al.* (2009) emphasized that efficient data collection with high accuracy is the key of e-procurement in order to purchase right material at right quality from right suppliers. Therefore, manufacturers need to formulate relevant supplier evaluation function and integrate the system with existing purchase processes smoothly through capturing accurate requirements from both suppliers and end-users in order to make effective the lean supply strategy over the EMSC infrastructure (Cheung and Liao, 2003; Lee *et al.*, 2009).

4.8 Conclusion and future research

In this research, a theoretical model was developed to study the relationship between lean supply strategy and continued adoption of sustainable lean manufacturing in an EMSC environment. Two indicative dimensions were identified that influence the adoption, namely, the extent of using lean manufacturing as sustainable practice and the degree of implementing lean supply strategy that aims to eliminate the eight manufacturing wastes. Four hypothesized relationships were developed for the model and were all proved to be statistically significant. Hence, it is concluded that supplier integration supported by an EMSC environment with the implementation of lean performance-based supplier selection policies significantly influences the use of lean manufacturing as sustainable practice. There are two major contributions in this study. First, this study proposed a structural approach to design and implement lean principle as sustainable manufacturing practice through combining practitioner's JIT approach (Buker, 1991) and academia's decision model (Rogers, 1995). Second, this study proposed a process approach to implement lean principle in supply management. As both supplier selection policies (pre-implementation) and supplier integration (practicing) had significant effect on lean manufacturing adoption,

this indicates that policies and practice need to be viewed as an integrated process rather than individual tasks. The study triggers future research. With EMSC infrastructure in-place and better supplier integration, implementing reverse logistics system that supports product recovery and goods return would become feasible in order to strengthen the capability of waste reduction. Nevertheless, the success of such system relies on customer's initiative of supporting environmental protection by delivering their used products to collection points which triggers the study of consumer attitudes toward the usefulness of and willingness to accept new idea in downstream supply chains (Lee and Chan, 2009; Liao and Cheung, 2002).

Chapter 5 CREATING AMBIENT INTELLIGENT SPACE IN DOWNSTREAM APPAREL SUPPLY CHAIN WITH RFID TECHNOLOGY FROM LEAN SERVICES PERSPECTIVE

The third article was published in the *International Journal of Services Sciences* (So and Sun, 2010b). As indicated in Chapter 1, the research in this study was solely conducted by the first author, i.e. the researcher, and was financially supported by City University of Hong Kong with the budget approved by the co-author. The first author is the only research staff recruited with this funding. The research studies a successful case of adopting lean services enabling technology to apparel retailing. The role of lean services in the downstream supply chains and how lean services can be realized in retailing by RFID technology are discussed. The results indicate that four major adoption factors in organizational aspects concerning compatibility and costs, and individual aspects related to ease of use and security and trust, are identified through positioning RFID as an innovative technology in contrast to existing practice.

The findings suggest that RFID needs to comply with standards or regulations of target markets as part of the industry requirements, and its products are considered advantageous if it could interoperate with the systems that are commonly used in practice. Moreover, RFID is in a better position if it is also compatible with the operation processes of the business so that the merger of RFID to existing operations demands minimal effort in terms of lead-time and resources. Also, the findings show that seeking long-term operating cost savings is one of the reasons that businesses implement RFID technology. In contrast to organizational factors which focus more on management competence, individual factors are usability centric focusing on the interaction between user and services, and the underlying technology. The findings reveal that first line support staff expect RFID could relieve their workload, while the merchant expects the ease-of-use attribute of RFID helps them capture the moment of truth so that sales can be closed sooner. Lastly, security risks, for example, leakage of personal data, unauthorized use of personal data or fraud transactions, is another user concern leading to reduction of trust for merchants, an issue that should be mitigated by taking proper security measures. In summary, these factors are useful for designing user-oriented services that realize lean principles appropriate for use in

the field by considering human factors.

Creating ambient intelligent space in downstream apparel supply chain with radio frequency identification technology from lean services perspective

Abstract:

Radio Frequency Identification (RFID) technology realizes ambient intelligence (AmI) in real-life and offers not only user-friendly shopping experience to customers but also agile and responsive store operations to merchants. Applying lean services in apparel retail operations may equally benefit to this industry. In this research, recent studies on RFID technology adoption were evaluated to help develop research instrument. It followed by a comprehensive case study on the implementation of a RFID-based smart retail system in an apparel retailer. Four adoption factors of this new initiative from both individual and organizational perspectives were identified: (1) *compatibility*, (2) *costs*, (3) *ease of use*, and (4) *security and trust*. A business value-added framework was then proposed for further research based on the adoption factors and lean improvement objectives. Lastly, managerial implications were discussed with the aim to provide insights of better adopting this technology through the alleviation of practical problems and user concerns.

5.1 Introduction

 The main applications in the first wave of radio frequency identification (RFID) have been in the supply chain mainly for improving the distribution of physical assets in the systems (Hardgrave and Miller, 2008; Sarma, 2008). The burgeoning use of RFID technology extends its applications to both upstream (supplier management) and downstream (retail and service) of manufacturing supply chains. RFID tags, also called "smart labels", together with other pervasive computing technologies realize AmI in real-life and make AmI become increasingly important in retail and services (Bohn *et al*., 2005). AmI represents the convergence of ubiquitous technology and computational intelligence creating an electronic environment (i.e. AmI space) that is sensitive and responsive to the presence of people (Aarts, 2004; Ramos *et al.*, 2008; Shadbolt, 2003). AmI is developed to enrich people's life and enhance customer experience in shopping and commerce that involve integrating tiny microelectronic processors and sensors into everyday objects to make them smart (Bohn *et al*., 2005; Friedewald and Costa, 2003). One of the latest smart AmI applications in retail is the intelligent mix-and-match of clothing items. In supporting this capability, a RFID-based smart apparel retail system was developed to help users choose desire colors and patterns that most closely resemble the style that one would like to portray, while on the other hand help apparel retailers manage product items on the sales-floor and inventory in the back store more efficiently (HKPolyU-ITC, 2007; Wong *et al.*, 2009).

Sharma (2008) argued that improving customer experience is a major objective of applying RFID technology in downstream supply chain. Other supply chain concerns such as *shrinkage* and *dwell time* of inventory management may influence the efficiency, operations visibility and total cost saving of store operations (Boeck *et al.*, 2008; Hardgrave and Miller, 2008; Kim *et al.*, 2008; Roh *et al.*, 2009; Sarma, 2008). Lean principles preach simplification and elimination of wasteful processes, which are applicable to address these supply chain concerns that bring inefficiency and provide little added value to customers. Becoming a lean enterprise enables retailers with the capability of improving operations, reducing costs, and delivering services with shorter lead times. Lean production was originated in Toyota with names "Toyota production system (TPS)" or "just-in-time (JIT)" manufacturing beginning back in 1960s which is now widely recognized as the most efficient manufacturing system in the world (Russell and Taylor,

2009; Womack and Jones, 1996). Similar philosophy has been used to apply lean in services, e.g. eliminating waste, improving efficiency and understanding the customer (Heizer and Render, 2007; Russell and Taylor, 2009). On this ground, lean was set-out to be the implementation objective of the new system aiming to improve store execution. However, performance gains of the user are often obstructed by the unwillingness to accept and use the available system (Davis, 1989). Apparel retailers should pay attention to the issues of users' resistance to this new approach and identifying relevant user adoption factors would be beneficial to the implementation of this innovative idea (So & Liu, 2007).

The studies of user adoption to new technology are not new. Problems related to user adoption to new technology have been brought to researchers' attention since the early 1960s (Lin and Ashcraft, 1990). Davis (1989) developed Technology Adoption Model (TAM) that helps organizations adopt new technology by considering human factors. This study attempts to explore and understand the circumstances that apparel retailers adopt RFID technology in an AmI environment from practical perspectives which aims to answer two questions: (1) what causes individual users of apparel retailers to accept RFID?, and (2) what can apparel retailers and their technological partners do to encourage the adoption of RFID?. To answer the questions, organizational and individual factors that influence the acceptance of RFID were examined. A case study on contextualizing RFID technology as an AmI enabler in apparel retailing concerning user acceptance was pursued.

This study provides insights to practitioners on the adoption of RFID technology with the aim to realize AmI in apparel retailing that add value to business from a lean service perspective. The participants of the study were asked to point to other possible circumstances that might affect one's decision on using RFID technology. The paper presents supportive literature on this technology, its applications and issues in apparel manufacturing supply chain and its adoption status in apparel retail and services. Also, the user adoption of a RFID-enabled smart apparel system aiming to improve store execution was evaluated based on the postulated factors derived from the case study. A business value-added framework theorizing the relationships among the RFID-based apparel system that supports lean services, its adoption factors and the improvements delivered by the new system was established for further research. Lastly, managerial implications of adopting this new initiative in creating a smart retail environment were discussed with the purpose to ensure the delivery of maximum value as a strategic tool for apparel retailers.

5.2 RFID technology and apparel manufacturing supply chain

5.2.1 Basics of RFID technology

RFID is an automatic identification (Auto-ID) technology developed by Auto-ID Center at Massachusetts Institute of Technology, relying on storing and remotely retrieving data using devices called RFID tags and readers (Auto-ID Center, 2002; Doyle, 2004; EPC, 2004; Finkenzeller, 2000; Shepard, 2005). With RFID technology, physical asset will have embedded intelligence that allows them to communicate with each other and with the tracking points (Auto-ID Center, 2002; IBM, 2003; VeriSign, 2004).

A RFID system essentially consists of three main components: RFID tag, RFID reader, and backend information system with middleware sitting between reader and backend system for carrying out data capturing, screening and routing (Glover and Bhatt, 2006). An RFID tag is a small object that can be attached to or incorporated into physical asset such as book, clothing, or person. When an RFID tag passes through the electromagnetic zone, it detects the reader's activation signal. The reader decodes the data encoded in the tag's integrated circuit (silicon chip) and the data is passed to the host computer for further processing (Finkenzeller, 2000; Hawrylak *et al.*, 2008; Shepard, 2005). RFID tags generally fall into two categories: passive, and active. Passive tags receive the most publicity and are currently being used by large retailers such as Wal-Mart and Metro to track inventory, and by the U.S. Department of Defense to track supplies (Hawrylak *et al.*, 2008). Unlike active tags, passive tags do not contain onboard power source and derive the power for operation from RFID interrogation signal in the course of communication (Finkenzeller, 2000; Hawrylak *et al.*, 2008; Shepard, 2005).

Passive RFID tags communicate using one of two methods: near-field and far-field (Hawrylak *et al.*, 2008). The far-field RFID tags support longer communication range than near-field tags, but are comparatively more sensitive to tag orientation. The type of tags required for a RFID system would depend on their business applications, site conditions and system design requirements. In case of supply chain and retail applications, far-field RFID systems are used extensively. According to Hawrylak *et al.* (2008), the sensitivity of the system to RFID tag orientation is critical in many applications. The communication method used by far-field RFID system easily causes false detection and hence the design of middleware and upper layer application software becomes critical in order to effectively

screen unwanted RFID signals emitted by nearby irrelevant product items.

5.2.2 RFID applications in apparel manufacturing supply chain

Tracking the movements of "things", i.e. items in supply chain can be determined by three variables in a three-dimensional space, in which the first two dimensions that each item in the supply chain traverses are "time" and "space" while the third dimension concerns with item identification by using RFID tags that carry Electronic Product Codes (EPCs) (Sarma, 2008). On this ground, RFID reader works with middleware to provide backend information systems with an "inventory snapshot" in its field of view which may cover a small corner of warehouse, distribution centre (DC) or backroom of retail store that essentially provides a series of item management function for improving the efficiency of supply chain operations including: (1) finding, (2) tracking, (3) tracing, (4) item count, and (5) time-intersections. Through querying of this corpus of data gathering from supply chain, two key metrics, i.e. *shrinkage* (caused by theft, damage, loss, and etc.) and *lead times* which concern supply chain visibility can be evaluated (Hardgrave and Miller, 2008). In particular for retailers in downstream apparel supply chain, the "lost sales" causing by (1) misplacement, (2) damage, (3) theft, (4) shipping error, and (5) counterfeit of items can be reduced with the use of RFID which ultimately lead to increased product availability and total cost saving (Ustundag and Tanyas, 2009).

Back in June 2003, Wal-Mart, a US retailer, strictly required its top 100 suppliers to implement RFID technology by tagging the pallets and cases in the supplies for operation improvement through sending real-time inventory data from individual store to suppliers (Hardgrave and Miller, 2008; Roberti, 2004). Wal-Mart and its suppliers use the real-time data to improve replenishment with out-of-stocks reduced by 16% by tracking cases of goods with RFID tags carrying EPCs, where this data enables suppliers to measure the execution of promotions and boost sales which benefit to both parties (Roberti, 2005; 2007). The Wal-Mart case demonstrates an RFID implementation that only predominately affects only a small portion of the supply chain (from retailer distribution centre to store backroom) and makes use only limited RFID system capability (e.g. finding and item count up to pallet level and case level only). Given this limited scope of supply chain exposure and application, determining the payback and ultimately creating business value is challenging.

	Distribution Centre (DC)	DC-BR	Backroom (BR)	BR-SF	Sales-floor (SF)
Time	- Dwell time - Code date	- Timeliness	- Dwell time - Code date	- Code date (seasonals, promotions)	- Customer experience
Quantity (Inventory)	- Automatic receiving - Real-time location system (RTLS) - Replenishment	- Shrinkage	- Assured receipt - Direct store delivery (DSD) - RTLS - Replenishment	- In-flow measurement - Shrinkage	- Automatic replenishment
Configuration	- Code/rule compliance	- Code/rule compliance	- Code/rule compliance	- Display/collateral	- Ensemble availability

Table 5.1 RFID applications in apparel manufacturing supply chain

The Demand Activated Manufacturing Architecture (DAMA) project, a part of the American Textile Partnership (AMTEXTM) representing a nationwide effort focused on increasing the competitiveness of the fiber, textile, sewn products, and retail industries during the last five years of work with the U.S. Integrated Textile Complex (retail, apparel, textile, and fiber sectors) has developed an inter-enterprise architecture and collaborative model for apparel supply chains with the goal of providing opportunity identification and improved high-level business process access leading to cost, time, and quality improvements to the U.S. Integrated Textile Complex (Chapman *et al.*, 2000; Lovejoy, 2009). Adapted from Sarma (2008), **Table 5.1** lists a map of RFID applications in apparel manufacturing supply chain based on the DAMA initiatives with the aim to improve item management in the "last 50 feet" of apparel supply chains that mainly concerns store execution (Hardgrave and Miller, 2008). The columns in **Table 5.1** represent different *locations* of an apparel supply chain delivering a series of storage operations, assembly/disassembly operations and transportation operations, while the rows represent different concerns in supply chain. *Time* concerns are prevalent with fast fashion or perishable goods in terms of maximizing turnover. *Quantity* concerns with having enough inventory to meet demand. *Configuration* refers to having not just the right goods, but the right combination of goods along the lines of various supply chain rules.

5.3 RFID-enabled apparel applications for lean service operations

5.3.1 RFID applications adopted by major apparel retailers

In the downstream supply chain, RFID technology works together with EPCs with the

initiative of standardizing the communication of product information so that the retailers can uniquely identify and locate information about the manufacturer, product class, and instance of a particular product (VeriSign, 2004). Aiming to automate supply chain logistic operations, EPC addresses everything from product items to packages, containers, and pallets (Auto-ID Center, 2002; Chorafas, 2001). On the basis of **Table 5.1**, retailers can: (1) uniquely recognize each item, (2) track the movement of items in the stores and warehouses, (3) automate business operations such as inventory management or point of sales (POS) activities, and (4) improve customer shopping experience such as providing recommendation on mix-and-match of product items through integrating RFID technology with other systems. In practice, RFID tags carrying the EPCs are directly related to product information down to item level in a typical retail application. Three cases are presented to illustrate how the application of RFID technology combined with the EPCs benefits retail management in the apparel segment:

(1) **Marks & Spencer**, one of Europe's largest retailers, has expanded its RFID deployment to include six clothing departments across 53 stores (Hess, 2008). The company uses RFID to track goods as they move throughout the supply chain into its stores. Apparel is individually tagged and eventually ends up on the sales floor. Store employees can quickly read racks of the RFID-tagged items by passing an RFID reader over the apparel. Tagging the items at the manufacturing point allows Marks & Spencer to monitor its shipments more accurately as they arrive in stores.

(2) **Levi Strauss & Co.**, a U.S. apparel retailer, demonstrated the value of RFID technology in inventory management through item-level tracking (Wasserman, 2006). The company has reported that sales clerks can complete a storewide inventory in about an hour, a process that used to take two days. That inventory data is used on the sales floor to replenish sizes, colors and styles of clothing. Levi says the in-store use of item-level RFID on clothing in Mexico City, which started in 2005, has increased sales.

(3) **American Apparel**, a U.S. apparel company, which operates more than 180 stores in 13 countries, is jumping into item-level RFID tagging and product tracking (O'Connor, 2008). The company saw quick benefits from the technology. The weekly process of taking inventory of all items in the store, which previously took four workers eight hours to complete, could now be accomplished with just two people in two hours. This gives employees more time to assist customers directly, and carry out other tasks.

As seen from these examples, many RFID-based apparel retail systems is mainly used to improve accuracy or efficiency of business logistics in relation to inventory management or checking out of product items but however cannot address all the concerns on sales-floor management as indicated in **Table 5.1**, e.g. improving shopping experience or item availability. RFID technology is traditionally offered to the retail segment for improving business logistics. Some apparel retailers use RFID technology in product authentication or article surveillance. Apparel retail is a season-driven and time-sensitive industry. In today's fast-paced society, customers with more sophisticated buying needs and increased choices but have less time to devote to shopping. Apparel retailers have to face the challenge of adapting quickly and efficiently to keep up with fashion and buying trends to meet customer demand, in view of the shelf-life of most product items are just around 20-40 days before their first markdown (Wasserman, 2006). An innovative system design with new configuration is needed for coping with changes. With RFID-enabled apparel applications, clothing items carried by customers can be automatically detected with mix-and-match recommendations shown in real-time (HKPolyU-ITC, 2007; Wong *et al.*, 2009).

5.3.2 Realizing AmI space in apparel retailing as lean services

Products of apparel retail are likely to be short-lived and the markets typically have the characteristics of (1) **short lifecycles**, as the product is designed to capture the mood of moment and hence the saleable period is likely to be very short, (2) **high volatility**, as the demand for these products is rarely stable, (3) **low predictability**, as the demand is extremely difficult to forecast because of its volatility, and (4) **high impulse purchase**, as buying decisions for these products are mainly made at the point of purchase (Christopher *et al.*, 2004). Apparel retailers face the challenge of adapting quickly and frequently to keep up with product change and buying trend to meet customer needs. In order to cope with the fast-paced characteristics and ever changing customer expectations, new method is needed for apparel retailers to better manage their shop operations in a more efficient manner as well as to bring customers with fresh new shopping experience so that they can stay competitive in the markets. Providing recommendations on mix-and-match of clothing by using computational intelligence is one of the AmI services in apparel retailing. With far-field RFID technology, AmI space can be realized in apparel shop through offering a variety of intelligent services with lean initiative which essentially extend the application of RFID to the "last 50 feet" of apparel manufacturing supply chains aiming to

improve the efficiency of store execution and in particular, address the concerns of sales-floor operations such as customer experience and item management (Hardgrave and Miller, 2008; Heizer and Render, 2007; HKPolyU-ITC, 2007; Russell and Taylor, 2009; Sarma, 2008; Wong *et al.*, 2009),

(1) **Mix-and-match recommendations** enhance *customer experience*, i.e. *time* concerns in **Table 5.1** such that the recommendations can be personalized for V.I.P. or registered customers based on their transaction history by discovering purchase patterns, i.e. estimating preferred choices through using data-mining technique or machine-learning algorithm. However, only standardized recommendations were offered to casual customers;

(2) **Inventory management** addresses the *quantity* concerns in **Table 5.1**, with visibility and efficiency improved by *tracking and tracing items* automatically in the back store and on the sales floor;

(3) **Article surveillance** brings *security control* capability by identifying and detecting items that are not check-out at the POS locations so that the *configuration* concerns in **Table 5.1** are addressed, and

(4) **Transaction process automation** includes the features like contactless check-out of items with bulk processing capability for improving POS workflow and ultimately customer experience (i.e. *time* concerns in **Table 5.1**) where these contactless features are not supported by conventional bar-code technology.

5.4 Overview of RFID technology adoption factors

Both individual and organizational factors are important in studying the adoption of RFID technology in apparel retailing. TAM (Davis, 1989; Davis *et al.*, 1989) and diffusion of innovation (Rogers, 1995) are widely supported from both perspectives in discussing new technology adoption. Recent researches on the TAM extended the original model based on the two central constructs, i.e. perceived ease of use (PEOU) and perceived usefulness (PU), to many different areas including e-commerce (Huang, 2008; Hong and Zhu, 2006) and particularly e-government (Dimitrover and Chen, 2006; Gilbert *et al.*, 2004, Hamner and Qazi, 2009; Horst, 2007; Karacapilidis *et al*., 2005; Tung and Rieck, 2005). At present, there are few empirical studies involved investigation of RFID adoption in apparel

retailing (Loebbecke and Huyskens, 2008; Moon and Ngai, 2008). Nowadays, RFID technology has been extensively used in the service domain and evolves into new form of integrated service applied in various business sectors, e.g. mobile payments and AmI for the application in smart home or retailing. Therefore, a review of recent studies on the adoption of RFID and related services was conducted aiming to identify the positive and negative adoption factors for developing questionnaire employed in the case study of this research. **Table 5.2** summarizes the various adoption factors with underlying contributing items as well as the corresponding supporting literature published in last five years.

Adoption factors	Contributing items	Source
Factors with negative effect		
Cost	Operation cost, subscription cost, investment cost	Au and Kauffman (2008), Brown and Russell (2007), Dahlberg (2008), Lai et. al. (2005), Mallat (2007), Moon and Ngai (2008), Müller-Seitz (2009), Ondrus and Pigneur (2006)
Security risks/concerns	Unauthorized use, transaction errors, lack of Transaction record and documentation, vague transactions; concerns on device and network reliability; concerns on privacy	Dahlberg (2008), Friedewald *et al. (2007)*, Hossain and Prybutok (2008), Mallat (2007); Müller-Seitz (2009), Ondrus and Pigneur (2006), Shih et. al. (2008)
Trust	With merchants, telecom operators, financial institutions or peer group, business partners	Dahlberg (2008), Friedewald *et al. (2007)*, Mallat (2007), Ondrus and Pigneur (2006), Thiesse (2007)
Complexity	Complex data input formats; complex registration procedures; other operations complexity	Brown and Russell (2007), Mallat (2007); Müller-Seitz (2009)
Compliance, Compatibility	Comply or compatible with regulations, standards or practices for integration with partners; sharing of resources or achieving lower product cost	Au and Kauffman (2008), Brown and Russell (2007), Dahlberg (2008), Hossain and Prybutok (2008), Lai *et al.* (2005), Mallat (2007), Moon and Ngai (2008), Ondrus and Pigneur (2006), Shih *et al.* (2008)
Stress, Pressure	Having psychological pressure or competitive pressure for adopting the technology	Brown and Russell (2007), Dahlberg (2008), Müller-Seitz (2009), Thiesse (2007)
Factors with positive effect		
Time reduction, Job/Task efficiency	Waiting time; job enhancement; process improvement	Au and Kauffman (2008), Kourouthanassis *et al.* (2007), Mallat (2007), Müller-Seitz (2009), Ondrus and Pigneur (2006), Thiesse (2007)
Ease of use/handling, Convenience	Operational ease of use	Au and Kauffman (2008), Dahlberg (2008), Hossain and Prybutok (2008), Müller-Seitz (2009), Ondrus and Pigneur (2006), Thiesse (2007)
Attitude toward new technology	In favour of using the technology of concern; perception of the importance of the technology	Leimeister *et al.* (2005), Moon and Ngai (2008), Müller-Seitz (2009)
Relative advantage	Have benefit or improvement comparing to existing practice, systems or technology (e.g. Bar-code); offering unique benefits that are not replaceable	Au and Kauffman (2008), Brown and Russell (2007), Leimeister *et al.* (2009), Mallat (2007), Shih *et al.* (2008)
Readiness	Readiness of both users and organizations influenced by past experience, expertise, knowledge, top management support, technical support, partner support as well as cultural factors; readiness for organizational changes	Brown and Russell (2007), Leimeister et al. (2009), Mallat (2007), Ondrus and Pigneur (2006), Shih *et al.* (2008)

Table 5.2 RFID technology adoption factors and supporting literature

Also, **Figure 5.1** depicts the frequency of appearance of the adoption factors shown in **Table 5.2**. The results show that four major negative factors, i.e. *compatibility*, *cost*, *security* and *trust* accountable for over 80% of the observations, while the top four positive factors i.e. *ease of use*, *job efficiency*, *readiness* and *relative advantage* represent 88% of occurrence. The results provide insights for studying organizations using RFID technology and help exploring consumer acceptance to this technology. Furthermore, the results have

implications to product developer as the references to design objectives formulation for new products as the adoption factors were based on the surveys involving hundreds of consumers and businesses in retail.
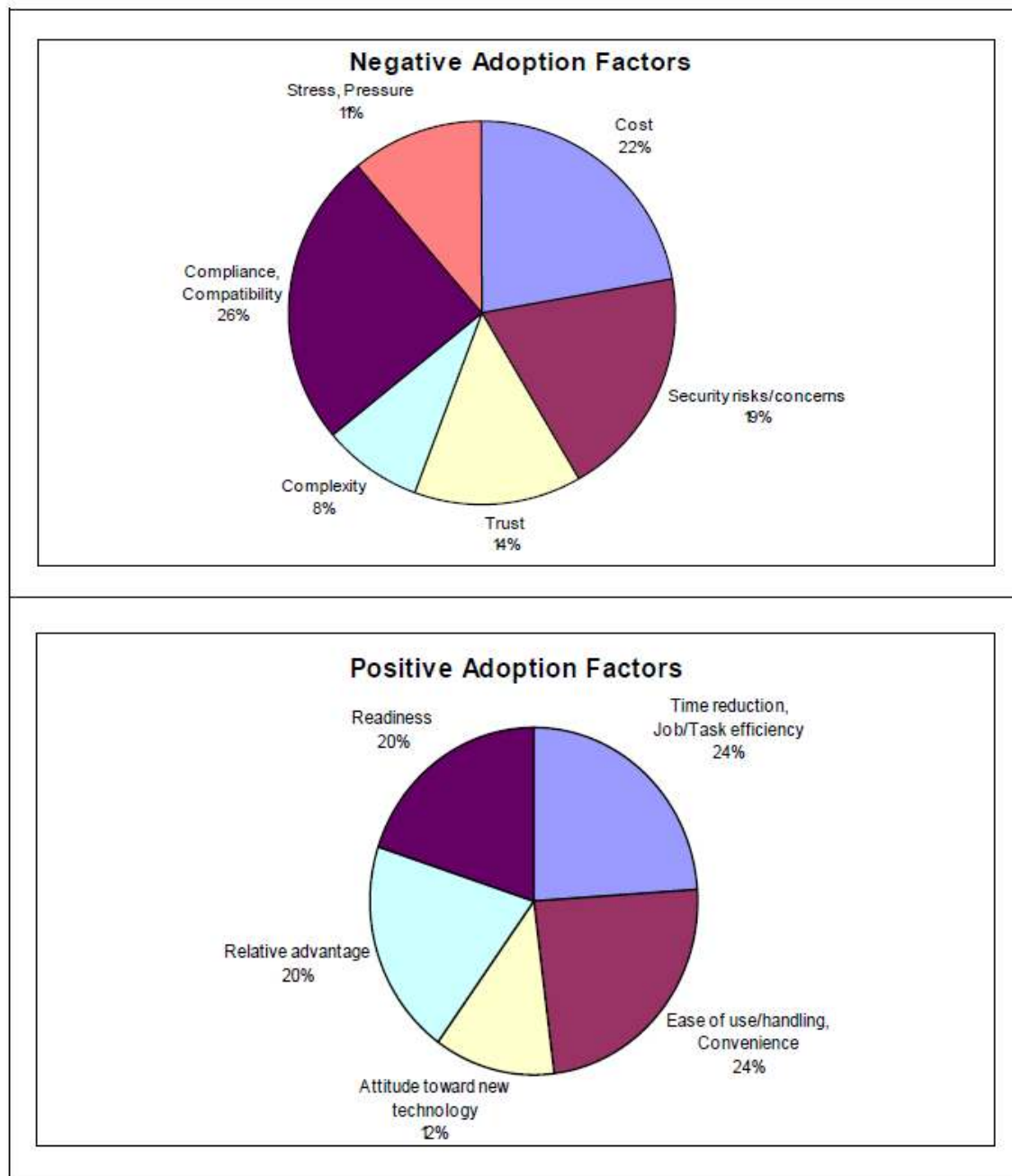
Negative Adoption Factors

- Stress, Pressure 11%
- Cost 22%
- Security risks/concerns 19%
- Trust 14%
- Complexity 8%
- Compliance, Compatibility 26%

Positive Adoption Factors

- Readiness 20%
- Time reduction, Job/Task efficiency 24%
- Ease of use/handling, Convenience 24%
- Attitude toward new technology 12%
- Relative advantage 20%

Figure 5.1 Profiles of RFID technology adoption factors

5.5   Research design

This study creates a qualitative research design to explore the circumstances that lead to the acceptance of RFID technology in the apparel manufacturing supply chain perspective. As the main objective of this study is to explore the adoption factors of RFID technology on realizing AmI in retailers of the downstream apparel supply chain aiming to provide insight to the industry, the research design clearly corresponds to an exploratory study based on real-life settings with case study method (Eisenhardt, 1989; Yin, 2009). In the following sections, the methods and scope of the research, research instrument, and lastly, research sites and data collection method will be discussed.

5.5.1   Methods and scope of the research

The study aims to explain the complex behavioral intention of using RFID technology to realize AmI in field and to establish valid and reliable evidence used for identifying adoption factors of this new application, case study research was used in this study considering its strength of its likelihood of generating novel theory and replicating or extending the emergent theory (Eisenhardt, 1989). Besides, the exploratory nature of case study research helps phenomenologist better understand and explain complex phenomena (Remenyi *et al.*, 1998; Saunders *et al.*, 2000; Yin, 2009). Case studies use multiple research methods supporting qualitative or quantitative approach (Yin, 2009). In this research, *an embedded single case study using qualitative approach was adopted* to explore the experiences of the interviewees on the use of RFID technology in the context of apparel retailing. The qualitative study helps soliciting views from end-users and management on their experience of use and behavioral intentions to accept RFID technology. The inductive approach of qualitative study allows the design itself to evolve, develop, and unfold as the research proceeds with the benefits of exploring new and unanticipated information to emerge from participants (Bryman, 2008; Cassell and Symon, 2004).

As part of a broader research program on manufacturing strategies, performance and practices and their deployment within supply chains, special emphasis is placed here on the RFID applications of a retailer in the downstream apparel manufacturing supply chain in the aspect of improving customer experience, operation efficiency and item availability. **Figure 5.2** depicts the scope of this research and its relative position in the supply chain. An apparel retailer, Firm A which deployed RFID-enabled apparel application was

evaluated in the case study research. Firm S, the technological partner of Firm A was involved in the study for exploring the technicality of the application.
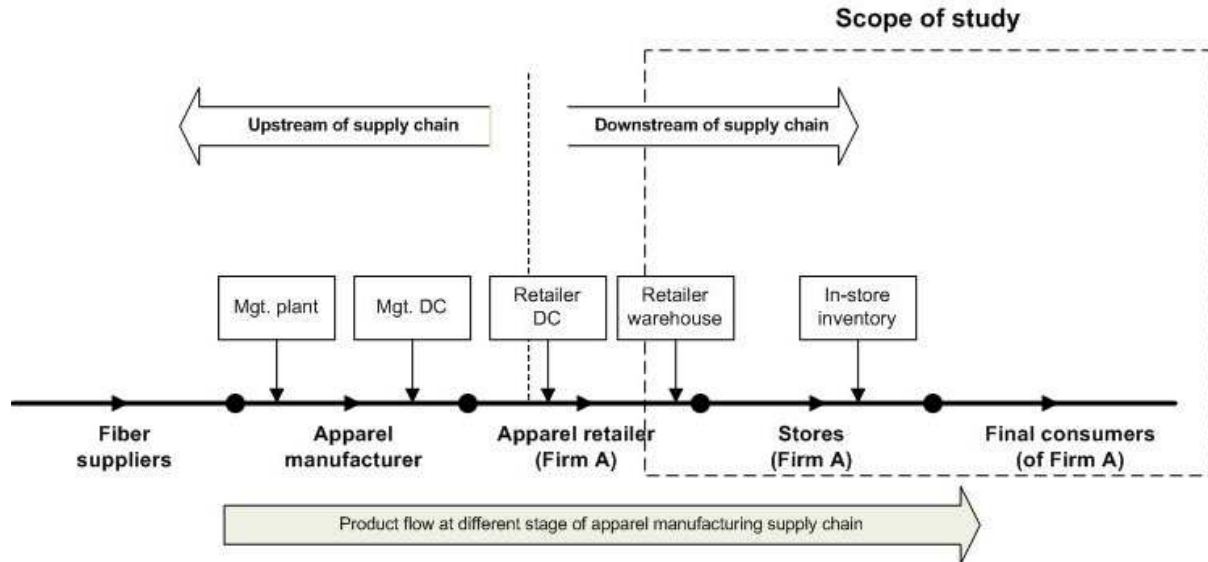

Figure 5.2 Scope of the study in apparel manufacturing supply chain

5.5.2 Research instrument

Based on the results of literature review as shown in **Figure 5.1**, there is an indication that adoption to RFID technology may be related to (i) *compatibility*, (ii) *costs*, (iii) *security*, (iv) *complexity*, (v) *potential to enhance job efficiency*, (vi) *relative advantage*, (vii) *ease of use* of the technology, and individual/organization's (viii) *trust*, (ix) *stress*, (x) *readiness* and (xi) *one's attitude towards new technology*. Hence, specific questions related to these factors were developed and included in the questionnaire to help explore and understand them. One-on-one interview was conducted with the participants by using open-ended questions.

5.5.3 Research sites and data collection method

Semi-structured interviews were conducted with Firm A, including first-line staffs at the retail stores who involve in using the technology and staffs at the back-office who involve in making related decisions. Triangulation was used to improve the validity of the study (Yin, 2009). Thus, the members of project and technical support team of Firm S were

interviewed to compare and contrast to the feedbacks from Firm A. Besides, informal observations were carried out on site where the researcher participated as staff member or customer. **Table 5.3** highlights the research subjects and corresponding data collection methods.

Participating firm	Involved parties	Data collection methods
Retailer (Firm A) in the apparel supply chain - Headquarter - Store	 - General Manager, IT Manager - Shop Manager, Customers	 - Interviews - Interviews, On-site observations
Technological partner of Firm A (FirmS) - Development - Implementation	 - Engineer - Project Manager	 - Interviews - Interviews

Table 5.3 Research subjects and data collection methods

In this study, content analysis of the replies to the open-ended questions and the text recorded in the observations was used for extracting the underlying attributes of user perceptions on using RFID (Carson *et al*., 2001; Graneheim and Lundman, 2004). The findings essentially represented experience and expectation from end-user perspective which were compared and contrasted with the practical design and implementation experience of the product developer so that realistic adoption strategy could be developed. The adoption factors were identified based on the findings.

5.6 Case study

5.6.1 Background

A comprehensive case study on Firm A and its technological partner, Firm S has been conducted according to the research design with the aim of exploring the adoption factors of RFID technology in realizing AmI space as lean services in apparel retailing in downstream supply chains. Prior implementing the new initiative, mix-and-match recommendations on clothing were provided to customers in old fashion way through staff members on the sales floor based on their experience and/or designers' suggestions by either showing photos in the product catalogues or locating the matching products on racks. Whilst, management of items on sales floor and inventory in the back-store was relied on the use of bar-code technology. Due to the constraint of bar-code technology, store

operation was highly manual base where the availability of staff was crucial as their full participation in the operation processes was required. In order to streamline the operation processes, Firm S has come-up a RFID-enabled smart retail apparel system in collaboration with Firm A. With the new system, customers are now provided with computerized recommendations on mix-and-match of clothing items with on-screened product information details, which offer a unique shopping experience ensemble to meet their buying needs instantaneously. In addition to customer relationship enhancement functions, the system enhances shop management by improving the efficiency of security and inventory management within the retail store.

Figure 5.3 Smart fitting room and smart dressing mirror

5.6.2   Lean service improvement with RFID-based apparel applications

The smart apparel retail system has a number of modules including smart fitting room and smart dressing mirror enabled with RFID technology with the promise to enhance shopping experience by offering responsive mix-and-match capability based on real-time analysis of customers' behavioral data stored in its database together with the implementation of essential shop management functions through realizing AmI features

over a lean service environment in Firm A's retail stores. **Figure 5.3** demonstrates the basic operations and flow of shopping process associated with the RFID-enabled smart fitting room and smart dressing mirror.

Both smart dressing mirror and smart fitting room are equipped with RFID readers embedded with middleware and intelligent apparel application which respond to any clothing item equipped with RFID tag associated with registered product ID and can be further associated with relevant product data and photo image stored in the backend databases on the in-house networks.

Figure 5.4 Roll-up and drill-down of mix-and-match recommendations

It is the design objective that **mix-and-match recommendations** are provided to customers in a faster and easier way than conventional human method. For arousing customer interest, smart dressing mirror is the first access point in fashion shop providing simple mix-and-match recommendations through image projection or high resolution TV display. When customer presents the tagged fashion items in front of the dressing mirror, the product images and mix-and-match image slide show of the products are displayed on the adjacent screen. Based on the recommendation, customer may proceed to the smart fitting room which equips with a touch-screen display with the capability of showing detail product information including product ID, price, color, size, as well as inventory status in an organized mean through the user interface of the apparel application. **Figure 5.4** shows

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the user interface of smart fitting room module. The product search flow is similar to the one provided by smart dressing mirror with which customer has previously accessed.

Figure 5.5 Active monitoring at ePOS and display of alert message

As shown in **Figure 5.5**, clothing items that were picked by customers were all tracked and recorded by the smart apparel system with valuable "on-the-spot" business intelligent data associated with customer identity. With the new system, customers are able to resemble the style that they want to portray in a more autonomous manner and less relies on the staff from the sales-floor. Besides, retailers may gain instant access to customer preferences and buying behavior captured by the system in the shopping process, enabling them to offer personalized product mix-and-match recommendations for customers as well as marketing strategies and business plans based on actual customer needs. In addition, the electronic point-of-sales (ePOS) module acts as the last access point in the shopping process through providing contactless check-out functions which is essentially part of the **inventory management** and **transaction processing automation** routines with the transaction records automatically updated in the database. Lastly, the **article surveillance** module plays the role of gatekeeper by generating alert message to shop assistants at the ePOS as well as alarm sounds if it detects any fashion item that was not properly check-out. The systems address all the three supply chain concerns, i.e. *time*, *quantity* and *configuration* as shown in **Table 5.1**.

5.6.3 Results and discussions

Not all people in the world favor "high-tech" services. Users may exhibit hesitation or even

have difficulties of using them that involve lesser human interventions, i.e. users apparently have no control on the outcomes. The result may jeopardize the original purpose of using RFID to realize lean services in store operation. Thus, understanding the motivations of apparel retailers to adopt and use RFID in retailing from the view of management, first line staffs in the store and customers may help better integrate the new technology to the business. Four major adoption factors from both organizational (compatibility and costs) and individual (ease of use and security and trust) perspectives were identified in the case study by considering RFID as an innovative technology in contrast to existing practice. In general, the results were satisfactory based on the feedbacks and informal observations from the field.

(I)   Adoption Factors

Compatibility

Compatibility of a product is an important determinant of technology adoption as it represents the consistency with the existing values, past experiences, and needs of potential adopters (Rogers, 1995). This organizational factor concerns both products developers and merchants implementing RFID technology. Their staff members were interviewed in the study. The compatibility of RFID technology was evaluated in terms of how compatible the technology is required with the contemporary regulations, standards or practices for the integration with partners, sharing of resources or achieving lower product cost. The findings suggest that developers need to develop RFID products complying with the corresponding standards or regulations of target markets as part of the industry requirements.

> "*Far-field RFID technology is based on the ISO18000-6 standard operating at the ultra high frequency (UHF) range*" (Engineer of Firm S)

> "*It is crucial to make the smart apparel retail system compatible with other RFID components by complying with EPC Gen2 standard (ISO18000-6c) from the supply chain integration perspective*" (Project Manager of Firm S)

RFID products are considered advantageous if it could interoperate with information systems that are commonly used in the retail business or more specifically in apparel retailing. For example, ePOS systems (front-end application supporting transaction

processing) and enterprise resources planning (ERP) systems (back-end application supporting inventory management as well as other enterprise business functions) are typical business applications used by retail companies. RFID products may be in a better position if they are compatible with the communication interface of these retail information systems.

> *"Maintaining several non-integrated business application suites is a nightmare as considerable number of manual tasks and control procedures to be fulfilled by IT department on a day-to-day basis. Stand-alone business applications with low compatibility with our existing systems unlikely appear on our shopping list" (IT Manager of Firm A)*

Costs

Cost advantage of a technology essentially represents its economic benefit which is considered as a relative advantage influencing adoption (Rogers, 1995). The ability of driving product development cost down obviously brings competitive advantage to RFID product developer, while it is also not hard to explain that apparel retailers are more willing to adopt RFID technology if it really helps reduce their operation cost and even with lower one-off investment. In fact, the findings suggest that seeking long-term operating cost saving is one of the reasons that the apparel retailer implemented RFID technology.

> *"The investment on the new technology was estimated to breakeven in 3 years as we hire less shop assistants and at the same time attract more businesses with this innovative idea in supporting sales and shop management" (General Manager of Firm A)*

Ease of use

Moore and Benbasat (1991) carried "perceived ease-of-use", i.e. PEOU from TAM as another measurement of relative advantage of adopting innovative technology if it can be used in a free-of-effort way. PEOU is important to both staff members on the sales-floor who are responsible for daily shop management and customers where the new system is expected to give them a unique and most importantly, "hassle free" shopping experience. The findings reveal that first-line support staffs expect the new system could relief their workloads rather than needing them provide corresponding technical support. Besides, the merchant would expect PEOU could help capture the moment of truth to close the sales

faster.

"The new system was supposed to provide customers with the ability of self-service shopping without human intervention. This idea was promoted to customers before they start using the system. It would be quite embarrassing if we need to provide additional technical support and this could jeopardize the original idea of using this system" (Shop Manager of Firm A)

"A picture is worth a thousand words. The eye-catching images projected on screen depicting mix-and-match recommendations are expected to help close the sales faster" (General Manager of Firm A)

Throughout the observations on the practical use of the new system in the retail stores, it was revealed that most customers satisfied with its performance. However, occasional delay was happened when showing photos of mix-and-match recommendation on screen. The delay was due to prolonged detection of tagged fashion items by the RFID reader embedded in the new system which was caused by improper tag orientation and the situation can be improved by fine-tuning the RF components, according to the product developer.

Security and trust

Previous studies on TAM have identified security and trust as perceived risks for a customer accepting new technology which are essentially the antecedents of PEOU and PU of the TAM (Hossain and Prybutok, 2008; Thiesse, 2007). In fact, our observations suggest that security is one of the customers' major concerns on the acceptance of RFID technology, especially for the VIP customers who have registered their personal data with the merchant previously.

"Will my personal data captured on this system be released to third parties?" (Customer A of Firm A)

"Will this cause unsolicited electronic messages sending to my cell phone or receiving marketing calls from agencies?" (Customer B of Firm A)

"How long is the data concerning my privacy retained on the system? I don't quite feel comfortable if my name was associated with these figures as they are kind of intimacy." (Customer C of Firm A)

The findings suggest that when applying RFID technology in the retail environment, it might involve perceived security risks (e.g. leakage of personal data, unauthorized use of personal data or fraud transactions) leading to reduction of trust on merchants. Yet, risks can be avoided or mitigated if RFID technology is adopted by taking proper security measures (So & Liu, 2006). For example, some practitioners argued that "*can users offer informed consent when they don't understand a technology or forget that it exists?*". The argument complies with the principles of many data privacy laws elsewhere in the world. The measure could help ease the concerns of security and privacy risks.

(II)   Business value-added framework

After identifying the adoption factors that motivate apparel retailers to use RFID technology in store execution, a business value-added framework (**Figure 5.6**) was proposed for further research in view of the lack of reported empirical research in the industry. The model aims to help management, practitioners and researchers better understand whether and how apparel retailers adopt RFID in lean services that create business values.
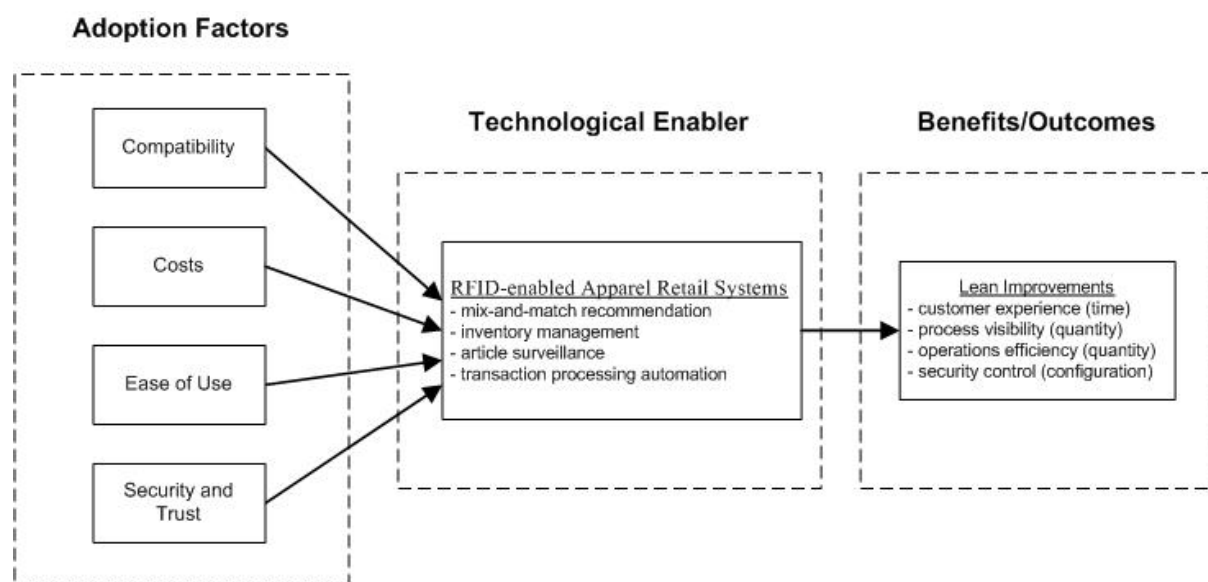

Figure 5.6 Conceptual framework

In this framework, a RFID system as the technological enabler of lean services driven by

four adoption factors creates values to an apparel retailer in terms of improving customer experience, process visibility, operations efficiency and security control as previously set-out to address the supply chain concerns on *time*, *quantity* and *configuration*. Thus, improved performance will enhance the overall efficiency of an apparel retailer, generate more sales volume, and increase profits eventually. As a result, all these benefits of new RFID initiative may potentially transform into a new practice in apparel retail.

(III) Managerial implications

The case study results and associated conceptual framework in previous sections have strategic implications to apparel retailers on realizing AmI space as lean services with RFID technology. Both the merchant (Firm A) and product developer (Firm S) have to consider various practical issues when implement the following services,

Mix-and-match recommendations

The strategic intent of offering visual effects and rich information to customers is to close the sales faster than the conventional approach. Addressing the concerns of using RFID technology is the key to success as the moment of truth can never be captured if customers do not actually use it. Based on the findings of case study, the problems associate with *PEOU* and *security* should be resolved before implementing the new technology on site.

Inventory management

Improving the accuracy and efficiency of operations is the purpose of applying RFID technology to inventory management. According to the IT Manager of the apparel retailer, the new RFID application software need to be integrated with existing system and hence, product developer has to design and develop their RFID products compatible with other major retail business application, e.g. ePOS systems and ERP systems. Without proper *compatibility* with other retail business applications, the use of RFID technology could be limited.

Article surveillance

Existing electronic article surveillance (EAS) devices which use magnetic technology are mature and competitive in prices. Though the apparel retailer considered the new RFID system could help save cost in long term, the cost of RFID-based EAS should be offered at

very competitive price in order to compete with existing technology. Otherwise, the new product is hard to survive alone but can only be distributed in bundling with other RFID components as total solution before existing products reach the end of their product life cycle. Hence, *time to the market* and *cost advantage* is important.

Transaction processing automation

Similar to the case of inventory management, compatibility of new RFID system with existing retail business applications is important. Further, many ePOS systems have already bundled with bar-code scanner as input device. RFID product developers may consider product integration with ePOS product vendors through forming strategic alliance. Therefore, both *cost advantage* and *compatibility* are the critical success factors in this aspect.

5.7 Conclusion and future research

The study explores various factors in relation to technology adoption concerning the use of RFID technology that influence the implementation of lean service operation in a retail setting. Research instrument was developed based on the review of related RFID literature. A comprehensive case study was then conducted and four adoption factors of the new initiative were identified: (1) *compatibility*, (2) *costs*, (3) *ease of use*, and (4) *security and trust*. In reality, getting new idea adopted, even if it has obvious advantages, is often very difficult which may take quite a lengthy period and may fail in the process of adoption (Rogers, 1995). Thus, managerial implications of applying RFID technology to lean services were discussed with the purpose to alleviate the practical problems and user concerns so that RFID can deliver maximum value to apparel retailers in which the most influential implementation issues include: (1) *PEOU*, (2) *security*, (3) *compatibility*, (4) *cost advantage*, and (5) *time to the market*. Furthermore, the study triggers future research. A conceptual model associating RFID apparel system with four adoption factors and lean improvement objectives (i.e. customer experience, process visibility, operations efficiency and security control) was proposed for further research by generalization in order to help better understand this topic.

Chapter 6   LEARNING FROM FAILURE: A CASE STUDY OF ADOPTING RFID TECHNOLOGY IN LIBRARY SERVICES

The fourth article was published in the *International Journal Technology Intelligence and Planning* (So and Liu, 2007). As indicated in Chapter 1, the research was financially supported by a research grant at Hong Kong Polytechnic University with the budget approved by the co-author, who was the head of department for whom the researcher worked. The first author is the only researcher in this project. The research studies a failed case of adopting lean services enabling technology to library operations by exploring the application of RFID technology in library services. Although the findings indicate that adopting RFID technology in the library has resulted in performance improvement in operations management, it also suggests that awareness of regulatory compliance is important in acquiring management practice from setting strategies, planning to implementation as it could involve extra cost and lead-time of launching the new services which jeopardize the original purpose of improving service levels and customer values. Thus, organization readiness in human aspects is important to the success of lean services.

The findings of the third article indicated that security and trust are one of the adoption factors for lean services, while the findings of the first article suggested that human factors are important to delivering a foolproof system for lean manufacturing. Negligence of these two factors in designing new services will probably lead to failure. The implementation issue that occurred in this case study demonstrates that the library staff may lack the skill and teamwork in designing the new library services, and the security and trust factors were ignored which led to none compliance with the data privacy law in Hong Kong. Results were additional costs of hiring professional consultants for problem resolution and the delay of the new services launch. The findings show that organization readiness is crucial to acquiring management system as it influences the entire firm's operations.

The case studies of this paper and the third article complement the first two studies through identifying human adoption factors based on user experience in real-life. They aim to contribute to designing services with lean principles that are appropriate for human use in the field and the development of a generic lean adoption approach aimed at improving entire supply chain competitiveness.

Learning from failure: a case study of adopting radio frequency identification technology in library services

Abstract:

One of the biggest myths about technology is the idea that any company can easily embrace it and comfortably expect results. However, successful implementation of a technology for an organization depends on many factors and organization readiness is most important. The readiness of strategy, people, process and system maturity should be assured for implementing the technology successfully. Radio Frequency Identification (RFID), an automatic identification technology that aims at enhancing customer experience and improving operation efficiency, is now widely used in different business sectors. It is not uncommon that problems, such as privacy issues in handling customer information and changes in workflow, appear in various RFID applications. This article attempts to give a brief introduction to this technology, highlight possible issues in its implementation and develop strategies to tackle the problems. A case study is presented, analyzing the organization's readiness for adopting RFID technology in a medium-sized library. Future improvement is proposed through learning from implementation failure.

6.1 Introduction

Libraries have made significant investments in computer-based resources, training and services underpinned by a combination of technologies. However, such investments need to be utilized effectively to add value to library services and avoid misuse or abuse. To meet investment objectives, library administrators need to take a proactive role in managing technology infrastructure. Advanced capabilities built on library infrastructure, such as automatic item and patron identification, tracking and tracing library materials, and personalized information services, can be helpful. To support these capabilities and integrate the underlying infrastructure into existing library operations, Radio Frequency Identification (RFID)-based integrated library system (ILS) can be developed to align with library functions and operating processes (Ayre, 2006).

RFID is widely used in many leading organizations in many business sectors (So, 2006). According to UPM (2006), a global supplier and manufacturer of RFID tags and inlays, RFID holds the promise of replacing existing identification technologies, such as bar codes. RFID is also used in many libraries to automate issuing and returning of books, videos and CDs and to give real-time visibility of library inventory. Until recently, books and CDs were identified with bar-coded labels, each of which had to be read individually with a bar code reader. Inventory control and reconciliation were a laborious and time-consuming operation. With RFID, books and CDs can be checked in and out automatically and inventory control can be automated with fitted scanners or their hand-held counterparts. The result is a reduced need for personnel and a much higher degree of accuracy in inventory management (TAGSYS and Sirsidynix, 2006; UPM, 2006).

Developing and implementing an RFID-based library system is highly achievable through carefully tested system design and implementation methodology. However, management should also pay attention to the risk of intruding on customer privacy in the course of distribution, processing and use of personal data as hidden, predictive customers information might be obtained in data mining or similar data management activities (So, 2004). It would be necessary for libraries to adopt restrictive measures in both administrative and technical aspects to prevent possible privacy intrusion.

This paper discusses supportive literature and establishes a generic model of ILS through integrating processes and utilizing RFID applications to optimize information flow

in library operations. The article also brings up the issue of possible intrusion of data privacy in the process of manipulating personal data of library patrons. A case study is presented to illustrate how an RFID-based ILS was used to improve operation performance of a medium-sized special library in Hong Kong, how personalized information services might potentially break the law and how the library management tackled the problems.

6.2 Evolution of library services

Libraries have traditionally performed a role of physical repository, housing print materials, with catalogues directing access to locally held resources (Maquignaz and Miller, 2004). E-library shifts the paradigm of the traditional role of library to that of online resources centre. The accessibility of the web facilitated this shift, and catalogue records describing local print materials now sit side by side with records providing links to both internal and external web resources. Although the inclusion of these electronic sources "enriches" library collections, it is, however, "inherently problematic" as such electronic sources do not have the traditional base of standards for inclusion that print materials do (Porter and Bayard, 1999). For example, conventional subject heading systems, such as Library of Congress Classification (LCC) scheme, cannot identify Internet resources.

With extended physical and virtual scope of library collections, library users experience greater difficulties in locating appropriate resources effectively. Generic search tools overwhelm users with unrelated titles. In order to cope with the increasing expectation and demand of digitally literate end-users, being able to provide rapid search and personalized information services is important to libraries. These services can be enhanced with the reading pattern of users shown in searching. Data mining will be a useful tool for this, as it is "the process employed to discover and analyze patterns in data and extract information" (Han and Kamber, 2001; Trybula, 1997). According to Nicholson (2003), data mining is the core of a larger process, known as knowledge discovery in databases (KDD). KDD is the process of taking low-level data and turning it into another form that is more useful, such as a summarization or a model (Fayyad *et al.*, 1996). In the past few years, several researchers have discussed the appropriateness of using data mining techniques in libraries (Banerjee, 1998; Chau, 1999; Nicholson and Stanton, 2003). Applying data mining in libraries not only can create better search tools, but may also help extract patterns of behavior-based artifacts from library systems (Nicholson and Stanton, 2003).

According to Ipsen (2004), "There is little doubt that RFID usage in libraries is becoming a necessity. There is pressure on both public and academic libraries to increase productivity and become more like "for profit" institutions and to do more with smaller budgets". From the operation perspective, many libraries want more than reliable security for their collections. They want to streamline collection management, improve traffic flow, speed up check-in and check-out, increase productivity, improve customer service and ensure collection accuracy (3M, 2006a-b). Some libraries collaborated with library management system (LMS) suppliers to develop ILS to achieve these goals and maintain a high level of security, such as combining RFID and data-mining technologies with conventional LMS (Checkpoint Systems, 1999; Kim, 2006; TAGSYS, 2006). ILS is expected to not only provide the capability of tracking and tracing physical library items, but can also offer personalized services. It is to ultimately become the enabling technology of one-on-one personal library services.

6.3 Fundamentals of RFID technology

RFID is an automatic identification (Auto-ID) technology developed by Auto-ID Center at Massachusetts Institute of Technology, storing and remotely retrieving data using devices called RFID tags and readers (Auto-ID Center, 2002; Doyle, 2004; EPC, 2004b; Finkenzeller, 2000; Shepard, 2005). Using RFID technology, physical assets will have embedded intelligence that allows them to communicate with each other and with tracking points (Auto-ID Center, 2002; IBM, 2003; VeriSign, 2004).
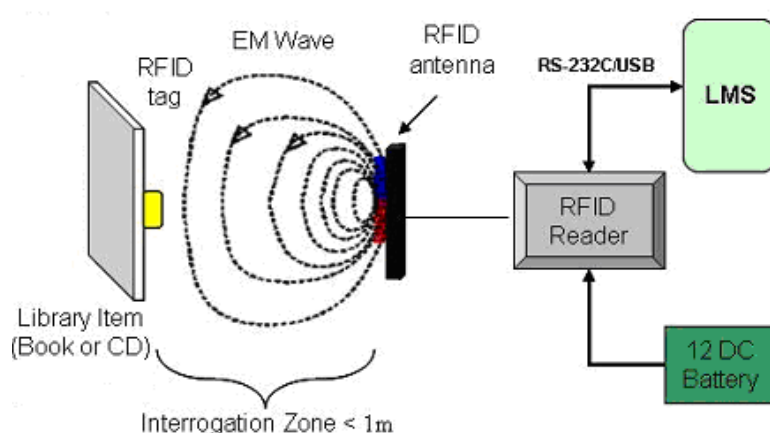

Figure 6.1 RFID System set-up for interrogating library materials

An RFID tag is a small object that can be attached to, or incorporated into, a physical item, such as a book, an animal, or a person. When an RFID tag passes through an electromagnetic zone, it is activated by the reader's activation signal. The reader decodes the data encoded in the tag's integrated circuit (silicon chip) and the data is passed to the host computer for further processing. **Figure 6.1** shows the basic set-up of RFID hardware for use in library management application (Kern, 2004; Singh *et al.*, 2006).

FREQUENCY	125 kHz	5-7 MHz	13.56 MHz	303/433 MHz	860-960 MHz	2.45 GHz
TAG TYPE						
Passive	ISO11784/5, 14223 ISO18000-2	ISO10536 iPico DF/iPX	MIFARE (ISO14443) Tag-It (ISO15693) ISO18000-3		ISO18000-6 EPC class 0 EPC class 1 EPC GEN II Intellitag tolls (Title 21) rail (AAR S918)	ISO18000-4 Intellitag µ-chip
Semi-passive					rail (AAR S918) Title 21	ISO18000-4 Alien BAP
Active				Savi (ANSI 371.2) ISO18000-7 RFCode		ISO18000-4 WhereNet (ANSI 371.1)

User Authentication & Identification

Library Asset Management

High Frequency RFID Systems

Figure 6.2: RFID protocol categorized by frequency and tag type

In general, RFID tag technology dictates the operating parameters of an RFID system. As outlined by ABI, Inc. (2002), other than tag power source, operating frequency is another major factor influencing the type of RFID applications, which can be categorized as: (i) low frequency (LF) for access control or point-of-sales (POS) applications, (ii) high frequency (HF) for handling baggage or library item in asset management application, (iii) ultra high frequency (UHF) for supply chain management (SCM) application, and (iv) microwave frequency for electronic toll collection application. The International Organization for Standardization (ISO) and EPCglobal are very active in developing RFID-related standards (EPCglobal is an organization leading the development of

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industry-driven standards for Electronic Product Code™ (EPC) to support use of Radio Frequency Identification (RFID) in fast-moving and information-rich trading networks). **Figure 6.2** illustrates the categorization of RFID protocol.

According to Arye (2006), there are two ISO standards applicable to library RFID systems. The current standard, ISO 15693, which defines the physical characteristics, air interface, and communication protocol for RFID cards, was not originally designed for item-level tracking used in libraries but for supply chain applications. Yet most RFID tags follow this standard. ISO 18000-3, a new standard designed for item-level tagging, was published in August 2004, which allows more secure communications between tags and readers.

6.4 Application of RFID technology in library services

RFID can help libraries identify and locate even the most remotely out-of-placed item, speed up inventory processes, and enhance customer experience through increasing product availability and delivering fast checkouts. This allows libraries to improve customer services and maintain inventory accuracy, which lead to more rewarding experiences for library patrons. In addition, information of library material utilization associated with the reading pattern of any particular users or user groups can be obtained by linking RFID data with LMS. The practical use of RFID technology in library management is shown in **Figure 6.3**.
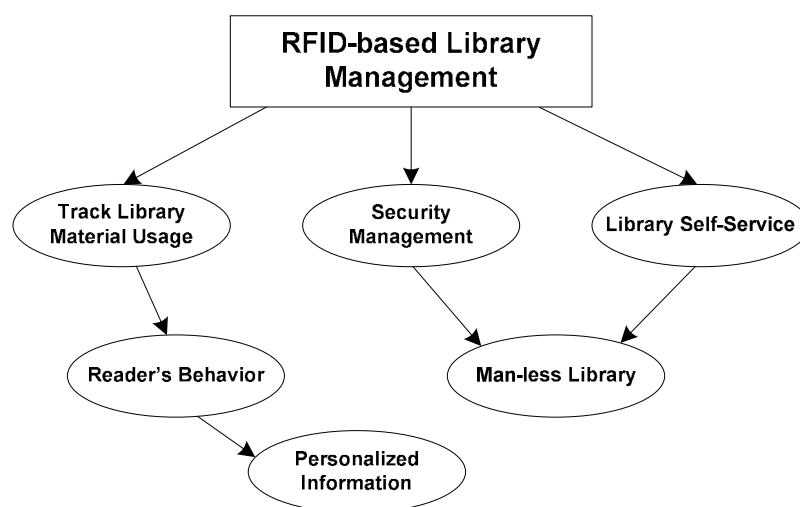

Figure 6.3: The use of RFID in library management

The following three cases illustrate how applications of integrated RFID technology in libraries benefit library administration:

(i) **National Library of Korea (NLK)** has introduced and operated an RFID system linked to its library card registration policy since July 2005. NLK aims to set up the foundation of Ubiquitous Library to provide high-end patron rights and upgrade services. With the application of an RFID system, NLK is able to provide a more convenient environment to patrons by allowing them to check out on their own using the self-check kiosk. Meanwhile, with the aid of the new technology, NLK is technically capable of handling a much larger collection (Kim, 2006).

(ii) **Farmington Community Library**, a U.S. public library serving the communities of Farmington Hill district, is the first library to install an RFID system in 1999. The company reported that the new system had reduced its time of stock-taking from four or five months to one day. The self-service function offers patrons privacy and enhances customer relations by eliminating long checkout lines, and frees up library staff to assist other customers. Furthermore, the check-out/check-in time by attendants has been reduced by as much as 80% (Checkpoint Systems, 1999).

(iii) **Shenzhen Library**, with the largest RFID library application in China and second largest in the world at present, has used an RFID system to realize the vision of a fully automated library where patrons can borrow and return library materials entirely on their own. The organization has reported that nearly two million RFID tags were integrated and installed on books, CDs, VHS tapes, patron cards, and other library materials. With the application of an RFID system, the library is capable of handling four million books, servicing 8,000 patrons and circulating 50,000 volumes per day (TAGSYS, 2006).

Seen from these examples, RFID helps libraries provide speedy inventory processing and enhance user experience by delivering faster checkouts. It also helps secure physical library materials. **Table 6.1** illustrates the memory mapping of 1024 bits Passive RFID tag implementation for library management, proposed by TAGSYS.

The design of RFID-based LMS aims to facilitate library circulation process through incorporating identification information (such as locations, items and borrowing status), even when library items are situated at multiple locations. As a result, the system can not only keep track of patron's borrowing history and the life cycle of a book (which enables

librarians to maintain better inventory) but also offer better security control (which facilitates self-services provision to library users) by following the circulation rules of the library (Kern, 2004; Singh *et al.*, 2006; TAGSYS and Sirsidynix, 2006). Thus, an "un-manned" library can then be developed with the potential benefits of reduced staffing cost and streamlined operations.

Field name	Space (Bits)	Capacity	Area	Write access	Memory
Reference Item	1	Binary Status	Recommended	Library Administrator	Write once, then locked
Locating data	5	Up to 32 sorts	Recommended		
Item type	4	Up to 16 types	Recommended		
Item identifier	48	A 15-numeric digit barcode number	Mandatory		
Multi-item ID	6	Up to 8 multiple items	Mandatory		
Extending Shelving section	32	- Up to 16 floors - 512 sections/dept - 8 shelves	Recommended	Managed by applicative software / Administrator Access at programming	Read / Write
Check-in/Check-out data	32	- CI/CO binary status - full data of the last operation - etc	Recommended	Automatic at CI & CO	
Library identifiers	64	- Maximum 8 alpha numeric digits, or - 2 alpha numeric and 12 numeric digits	Optional	Managed by applicative software / Administrator Access at programming	Write once, then locked is recommended
Free use	>800b	16 numeric digits	Optional	free	According to the data stored

Table 6.1: Memory mapping of RFID tag for library management

Furthermore, more than 800-bits free-for-use RFID tag memory is reserved for libraries to implement value-added applications, such as tracking usage patterns of patrons and tracing physical library items. However, such free-for-use memory may potentially contain patron's personal data, which is particularly useful for tracking patron's preference. Library administrator should pay attention to the security measures concerning confidentiality and data privacy (So, 2006; So and Liu, 2006; TAGSYS, 2005).

People are often interested in stories of success but shy away from those of failure, yet valuable lessons can be learned from failure to help achieve future success (Kam, 2006). The above cases are all success stories of applying RFID in libraries. However, the barriers to success and how people and organization learn from failure to achieve success in RFID implementation are not discussed. In the following section, we present a case study of a medium-sized special library implementing an RFID system, and discuss how the library made improvements through learning from its setbacks.

6.5 Case study

Similar to other privately owned libraries, the YFT Biblical Institute Library (YFTL), a medium-sized special library in Hong Kong, is facing the same challenges to improve customer satisfaction and reduce operating costs in the face of budget shortfall. Library budget is tight, and increasingly, it is trying to expand services and extend opening hours while coping with increasing circulation needs. Automating library operations with self-check systems is one way with which that increasing circulation can be managed without having to increase staffing.

YFTL aims to become a fully automatic library and provide self-check systems with the use of RFID technology so that library utilization can be increased and more funding can be attracted for future development. In the hope of tackling these challenges and establishing more profitable relationships with users, YFTL started its RFID-based library initiative two years ago. In 18 months, the library has gone from feasibility study, planning, design to implementation with the help of RFID library system consultants. The consultants have extensive system analysis experience and positioned the reengineer project as a system development project. Basing on the theory of Semprevivo (1982), the consultants developed a system analysis model, shown in **Figure 6.4**, for the implementation of an RFID system in YFTL.
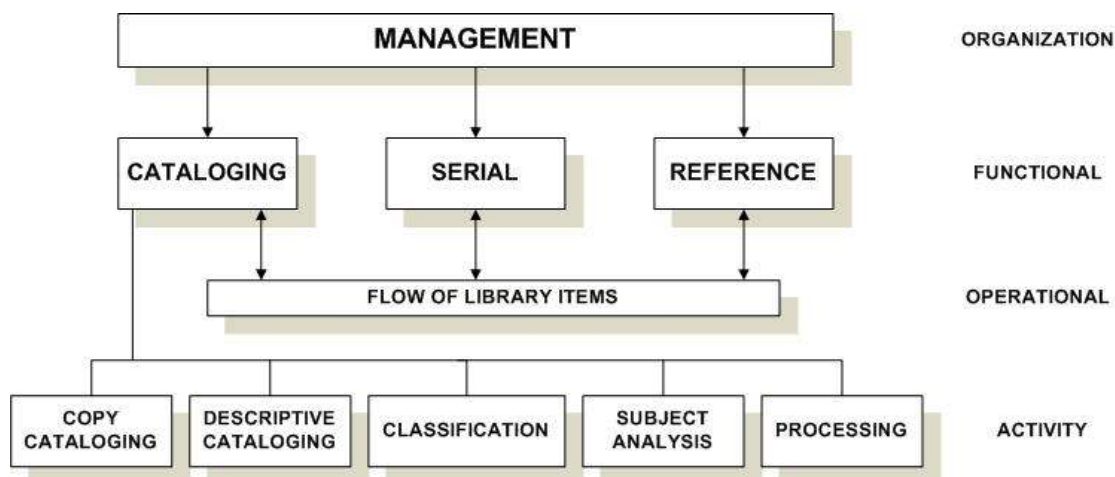

Figure 6.4: The system analysis model for YFTL

The system analysis model is divided into the following four levels:

(i)   **Organization:** Changes needed to make the new system works will profoundly affect the organization. The analysts performed an organization-wide management audit and carried out focus group workshops for the implementation by considering the following factors: (a) coordination of all departments, (b) human resources, (c) time, (d) financial resources and (e) compromises within the library. The library administration then developed a project implementation plan based on the result.

(ii) **Functional:** The requirements of each major functional group of the library were assessed, aiming to estimate the required capacity of the system as well as to reduce the impact of changes and the risk of failure. The analysts interviewed the managers responsible for cataloguing, serials and reference to collect requirements and performed impact analysis.

(iii) **Operational:**   Process flows at operation level can be intradepartmental or interdepartmental. For example, Serials management in a library involves the departments of acquisition, processing and circulation. Analysis of interdepartmental operations involves more coordination than that of intradepartmental ones, and can require more time than anticipated.

(iv) **Activity:** All procedures within every single function were studied in detail. The process of reshelving books after they are discharged is an example of an activity. Conducting systems analysis at activity level involves detailed analysis of work processes, their associated materials and information flows. Introduction of new systems that improve operation efficiency and service quality always involves changes of existing workflow.

6.5.1   Major system components of an RFID-based library

RFID technology complies with ISO 18000-3 standard, with the objective of standardizing library operations management so that the system can identify and locate information about a particular library item, such as its borrowing status, section class, and to which library it belongs (TAGSYS, 2005). The following system components underpin the basic operations of RFID-based library management, including patron identification, security control and library circulation process handling.

(i) **RFID Tags**: Each RFID tag has a non-powered radio antenna, which can be communicated with through a powered antenna belonging to a tag reader on a scanner or security gate. There are two main types of RFID tag used in library applications:

- *Standard tags* – Standard tags are used on books, magazines, affixed directly to the face of a video (in most cases covering one of the windows) and can be affixed to cases for those CDs and DVDs that have metallic content.

- *CD/DVD tags* – There are circular tags, which are used on CDs or DVDs. These tags can be directly affixed to the inner circles of CDs and DVDs that have no metallic content.

(ii) **Multi-purpose Station (MPS)**: User-friendly workstations are used by patrons for checking in or checking out library items. Multilingual and easy-to-use instructions are provided to assist patrons.

(iii) **Security Gates**: Electronic Article Surveillance (EAS) is an anti-theft system used in libraries. This security feature is incorporated with RFID technology in the tag and is activated or deactivated during check-in or check-out. Security gates with this capability can detect EAS status. This plays a crucial role in preventing loss of library items, typically by setting off an alarm when an unauthorized checked-out item is detected. This, coupled with CCTV and smart-card controlled turnstile, can further enhance security of library items.

(iv) **Library Management System (LMS):** This is a software system that works with RFID hardware infrastructure to manage circulation process, including self-checking, security control and other MIS functions required by library administrators.

6.5.2 Development of RFID-based library management

In order to properly align and integrate library operations with major system components, a three-tier hierarchical implementation model is formulated according to the finding of the system analysis study conducted for YFTL. The implementation model is shown in **Figure 6.5**.
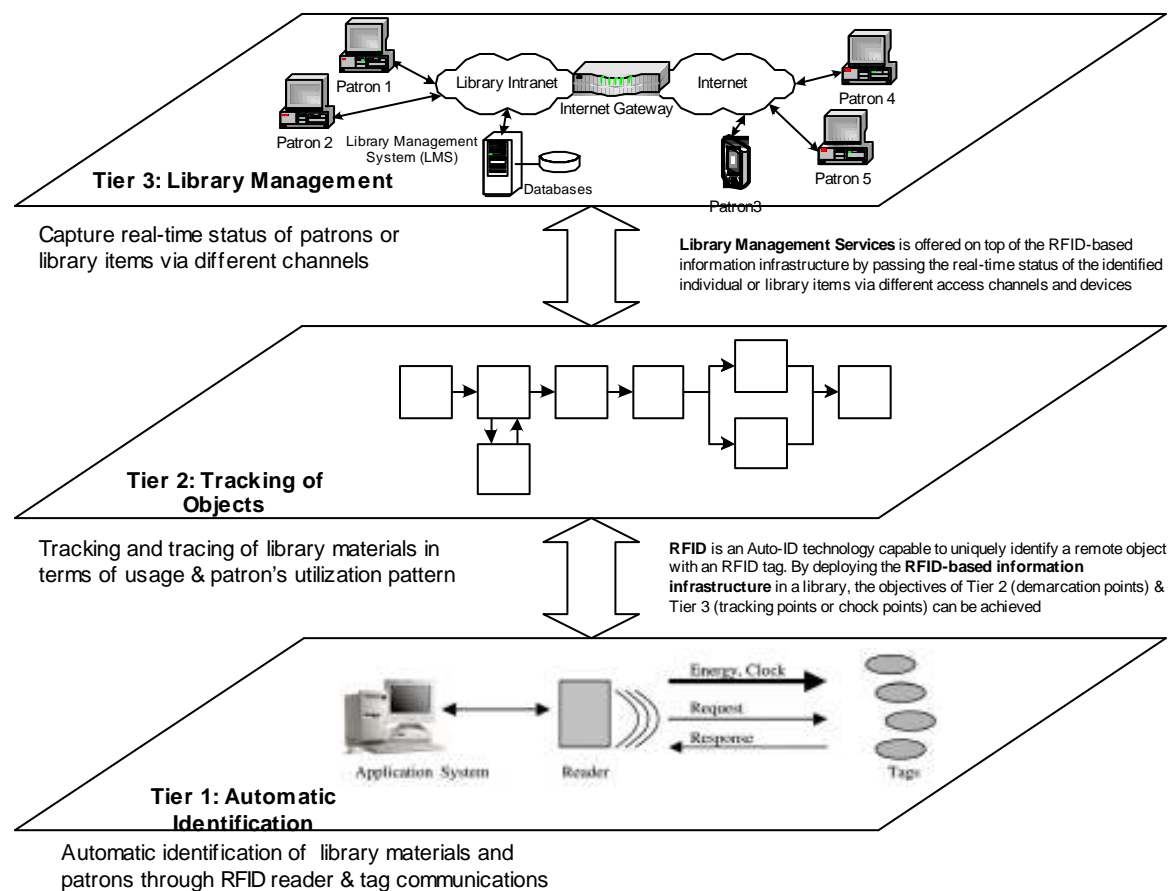
Figure 6.5: Three-tier library operation model

The hierarchical implementation model consists of the following functional tiers:

(i)   *Tier 1* involves RFID hardwares, which include security gates and readers installed at access points of the library. The smart-tags are attached to library materials to provide automatic identification and authentication.

(ii)   *Tier 2* involves further development of RFID hardwares, including antenna and multiplexer installed at tracking points to keep track of the movement of library items and capture real-time status information for LMS to perform information management.

(iii) *Tier 3* automates library management through providing self-checking of library items, locating out-of-location items and enabling utilization analysis to be carried

out by LMS. Most importantly, personalized information service is provided on top of RFID infrastructural hardware through integrating a software module into LMS to perform personalization function that aligns with the usage pattern of patrons.
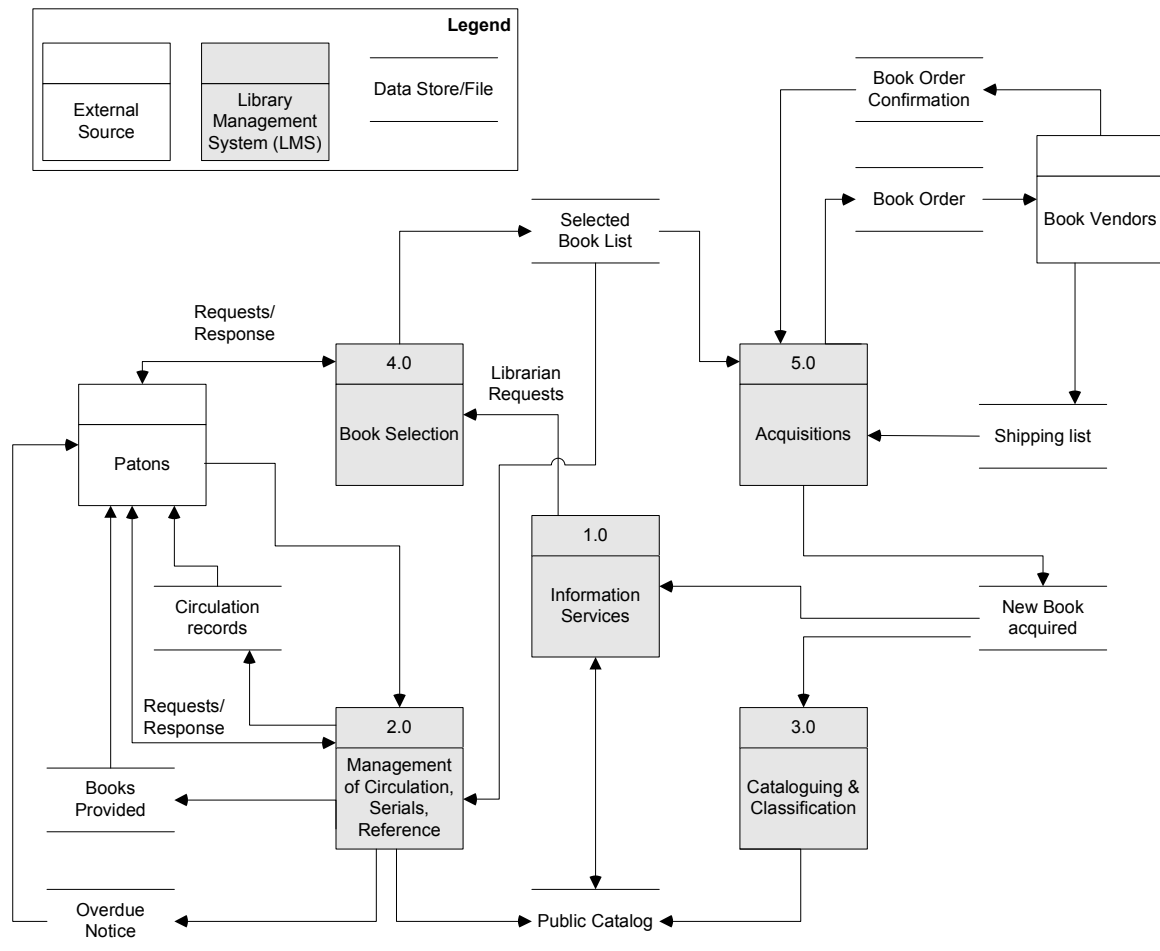

Figure 6.6: Data flow diagram between LMS and external sources

Tier 1 and Tier 2 of the model essentially implement RFID hardwares and related middlewares that form the underlying system infrastructure of the library. Tier 3 of the model provides library system functions. Data flows (with external data sources) between these functions are illustrated in **Figure 6.6**. In essence, the continuous flows of information in library operations create a library information network that moves the data from RFID readers, to RFID middleware and then to LMS server, and data is shared within the library in real time. This is to enhance operation visibility and service quality.

6.5.3 Improving operation visibility with RFID-based library management

In practice, RFID tags carrying identification and status bits are directly related to library item information hierarchically at item level, section level and library level. As library items move around the library, continuous flows of real-time status data are captured at various RFID access points so that operation visibility is increased. The improved visibility of item flows, locations, utilization level and borrowing status of library items helps library administrators gather and link item information to their database to improve efficiency in acquisition, budgeting and exception handling throughout the operation process. **Figure 6.7** shows the operations flow of the RFID-based library.
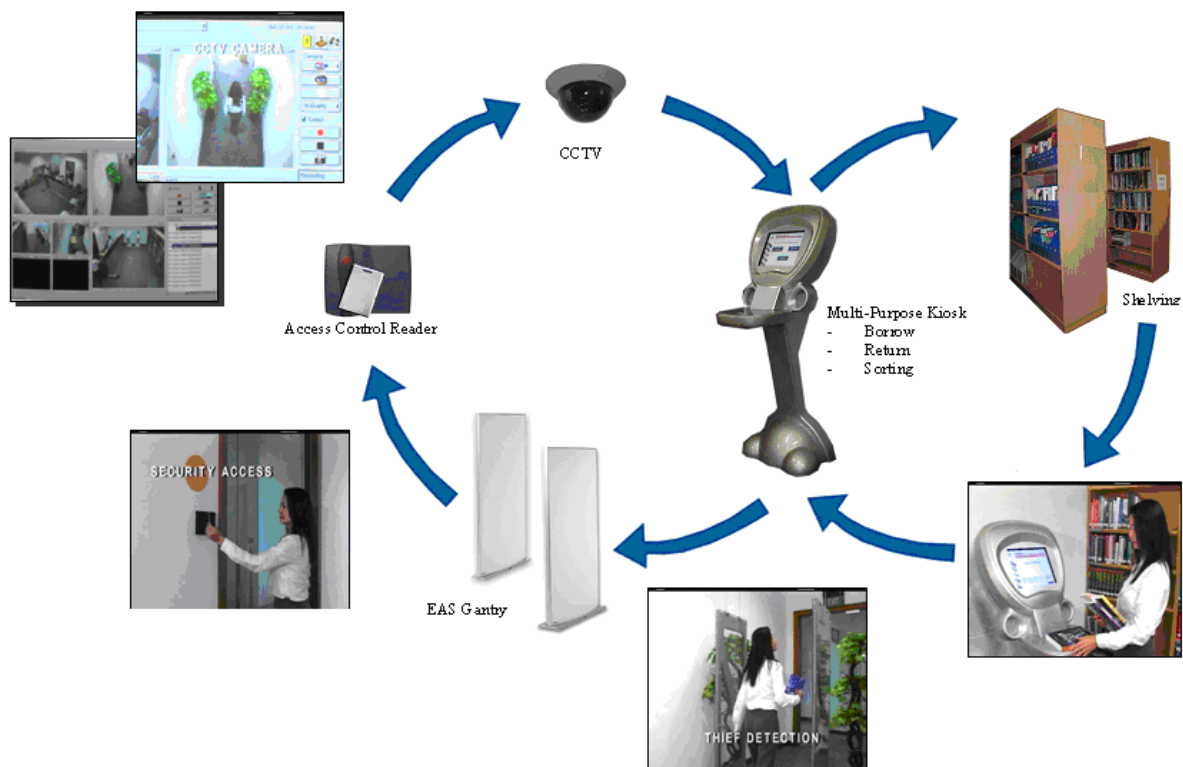

Figure 6.7: The operation flow of an RFID-based library management

Tracking users' reading history on checked-out library materials is achievable through extracting relevant information from the database of a conventional LMS used for library item circulation management. However, tracking the usage pattern of in-library printed material is different, as in-library materials do not go through proper check-out process.

The "real-time tracking" features provided by an Integrated RFID-based library system (Arye, 2006) can help resolve this issue through offering the capability of following item movement (e.g. location, time, etc.). Another part of Tier 3 functions is personalized information service. **Figure 6.8** shows the functional building blocks of an ILS that delivers personalized search result.
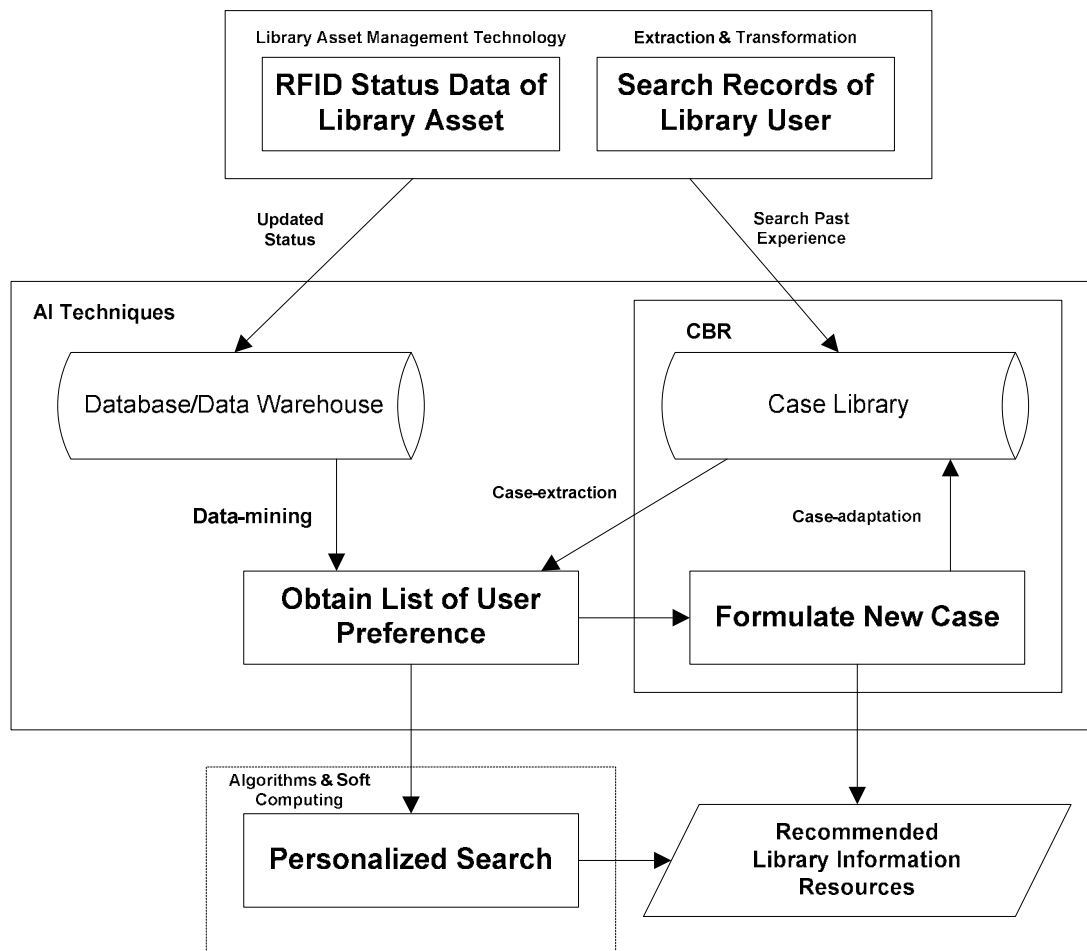

Figure 6.8 Functional module of ILS that offers personalized search

ILS employs a distributed computing design by coupling RFID with Data Mining and Case-based Reasoning (CBR). An integrated library information management platform was developed with the intention to improve library services through providing personal library resource search function to individual patron. CBR involves making use of past cases to perform new tasks (Kolodner, 1993; Watson, 2003). It is an Artificial Intelligence (AI) technique that enables ILS to provide an intelligent way of tracking users' reading

patterns and develop personalized information. The search result is personalized for individual patrons based on their previous search history as well as reading patterns. By calculating the feature similarity between a new case and past cases, similar cases can be retrieved and reused for new search (Choy *et al*., 2003a-b: 2004). Applying CBR and data mining technologies, ILS provides patrons with more relevant library resource search results according to the patrons' reading preference and borrowing history.

6.5.4   Implementation and operation issues

A number of issues arose from the implementation of ILS at YFTL. Organizations need to anticipate both technical and non-technical problems when implementing RFID technology because process changes, data conversion and systems integration are carried out not only within the firm, but also among its trading partners. The suitability of YFTL to adopt ILS was evaluated in accordance with the following aspects:

(i)   **Strategic Management**: To evaluate if the management has the strategic vision to create values in customer processes through re-building the processes to cope with new strategic goals. The business model was assessed to see if it could support the vision and offer appropriate services to users.

(ii)   **Execution & Operations**: To evaluate if the operation processes can properly underpin the strategic direction so that efficiency in daily operation can be improved and problems solved.

(iii)   **Technology**: To evaluate the readiness of the Information Technology (IT) of YFTL, as IT is a key enabler to underpin management strategies and operations through ensuring confidentiality, integrity, and availability of information.

(iv)   **Change Management**: A major change would happen not only on the existing information systems, but also on various organization components, such as culture, structure and strategy. A change management process, overseeing by the management and an executive committee would be established.   Ineffective change management could lead to disastrous outcome, as problems may arise in neglected cross-functional communications, strategic misalignment and overlooked cross-functional synergies among affected departments.

(v)   **Project Management**: Project management approach, such as structure of project

management team, methodology and implementation planning, would be assessed. These are part of the critical success factors for project implementation.

Issues in the course of implementing ILS at YFTL can be identified. The results are summarized in **Table 6.2**.

Areas of evaluation	Findings	Major problems
Strategic management	YFTL management has strong commitment to support the initiatives of using RFID technology	Nil
	YFTL management is able to drive the key staff at operation level to automate the library with RFID and redeploy staff at the frontline to provide value-added services	
Execution and operations	Execution The RFID technology can be smoothly integrated into the LIS and workflow	Execution Nil
	Operations Data privacy may be abused as personal data was used in data mining	Operations Without proper scrutiny when applying user's data, patrons may be reluctant to maintain a closer customer relationship. YFTL may face legal action if data privacy was abused that lead to law breaking
Technology	The RFID technology used for library asset management is mature and stable	Nil
Change management	YFTL management establish and lead the change management committee to approve and control the changes in the project, including process, human resources and technology in order to make sure the implementation is carried out smoothly	Nil
Project management	YFTL management champions the project team with relevant project management methodology with proper control on time, cost, issue, change, human resources and risk.	Nil

Table 6.2: Major problem of adopting ILS at YFTL

It appears that there are no major technical and non-technical problems reported in the

course of implementing RFID technology in YFTL, except the possibility of violating data privacy in the personalized search function of Tier 3. Although data mining helps businesses build a better relationship with patrons, this capability may add to the risk of intruding on data privacy of patrons. Without proper security measures for user data, patrons may be reluctant to maintain a close relationship with YFTL and they may even pursue legal action against YFTL their personal data were abused. Therefore, YFTL ceased rolling-out the service of personalized information before the issue could be properly resolved.

6.6 Problem analysis and discussion

YFTL employed a legal advisor and an information security consultant to help sort out the problem. It was suggested that the vulnerabilities in data management activities concerning personal data should be identified, followed by the adoption of appropriate restrictive measures to prevent privacy intrusion of personal information. The information security consultant developed security policies for YFTL. Specific baseline security controls are indicated in the policies and were implemented as restrictive measures to solve the problem.

Restrictive measures are applied in the areas of information security, systems security and personnel security. Information security is concerned with ownership, accountability and classification of information. In order to properly mandate the implementation and ensure application of security policies, business owners must be identified, and information must be classified according to its confidentiality, integrity and availability (CIA) to be managed by its owners. Systems security is about password management and virus control for safeguarding the information. Personnel security concerns the control of third parties who access or process the data. Administrative controls are involved to maintain information confidentiality and integrity.

6.6.1 Fundamental sequence of data management activities

The consultant identified the sequence of data management activities in YFTL which showed how and where privacy restrictive measures should focus. It was suggested that restrictive measures should be placed at major check points along the data management process.

There are three main stages in data management process concerning the manipulation of personal data, namely, (i) acquisition, (ii) analysis, and (iii) use. Each stage consists of one or more major data management activities. **Figure 6.9** shows the flow of personal information processing at each stage.
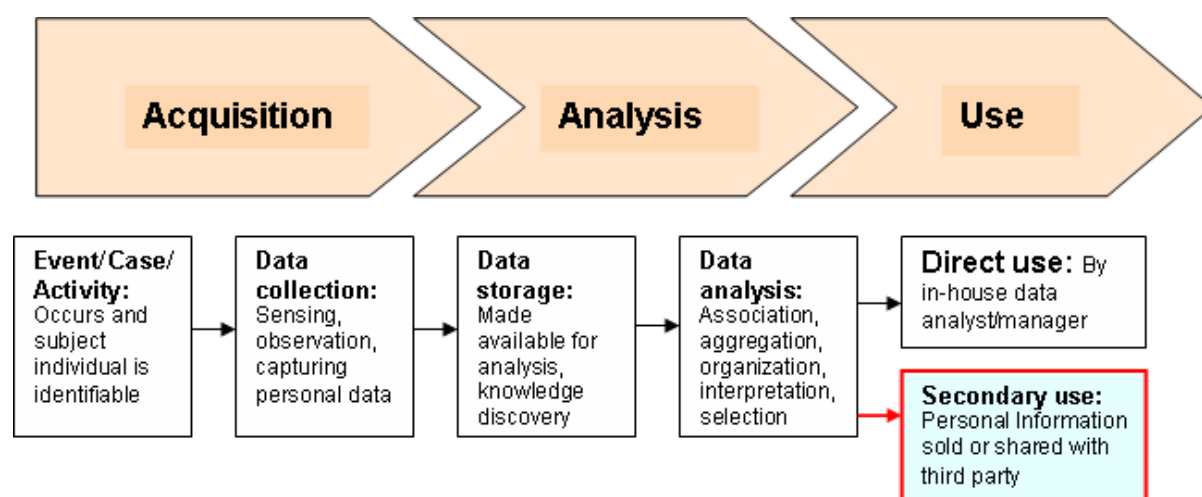

Figure 6.9: Major data management activities of personal information

These activities actually form an information distribution chain and value is added at each stage. The later the stage where data is produced, the higher the value associated with it and the greater help it is for decision making. There may be harm to library patrons when there is misuse/abuse of personal information. Focus needs to be placed at the point before personal data is distributed for use.

6.6.2 Protection of personal data privacy by law

If the "handlers" of personal information are regulated under privacy law, this focus shifts from the chain of distribution to the chain of custody. Custody recognizes that subject individuals have rights in their own information and that privacy regulations regulate the activities of information handlers in the three main stages of data management.

In Hong Kong, Personal Data (Privacy) Ordinance was enacted in 1995 to protect individuals' personal data. It imposes six privacy principles that apply to any persons (data users) who control the collection, holding, processing, security and use of personal data.

The coverage of the ordinance is summarized in essence in **Table 6.3**.

The personal data should be	The data subject should ascertain
Collected only if they are relevant to the data user's activities and in a manner that is lawful and fair	A data user's *policies and practices* and the kinds, and main purposes, of personal data held
Accurate and not *retained* longer than necessary	Whether data are held relating to that individual and have the *right to access* and *correct* such data
Used only for the purpose(s) for which the data were to be used at the time of collection, unless the data subject expressly consents	
Held securely	

Table 6.3: The coverage of personal data (privacy) ordinance

The Ordinance establishes a comprehensive framework to regulate the use of personal data and applies to both the public and private sectors, computerized and manual data. It generally provides good control over the three main stages of data management process. On regulating the use of data, Principle 3 of the Ordinance states:

> *"Unless the data subject gives consent otherwise personal data should be used for the purposes for which they were collected or a directly related purpose."*

However, exemption from Principle 3 is allowed under certain conditions. Section 62 provides exemption from Principle 3 where data is to be used solely for preparing statistics or carrying out research.

With exemption, data users may transfer personal data to third parties, such as market researchers conducting surveys or other research activities, without getting consent from data subjects, though research results are restricted so that data subjects are not identified. However, the possibility of data abuse by third parties remains if no proper control is imposed in the organization's distribution chain. It is suggested that data users should adopt appropriate restrictive measures to prevent abuse of personal data from happening to data subjects.

6.6.3 Security control on handling personal data

The basis of security control is that accountability and responsibility can be properly defined and exercised to secure information and control data users where personal data is part of a critical business information asset. The business owner of YFTL was identified with clearly defined responsibilities such as authorizing access of data, mandating the implementation of security controls through making sure all user access and privileges remains current, and, most importantly, accepting any risk associated with the non-implementation of security controls. These are important for the effective application of security controls in the library.

Area of control	Descriptions
Ownership and responsibility	Proper role and responsibility for managing information asset should be clearly defined including at least the following: Business owner with overall responsibility on business information, including personal data Information systems owner Security administrator who manages the proper execution of security guidelines.
Classification of information	Business information including personal data, should be classified according to confidentiality, integrity and availability (CIA).
Information/ process protection	Personal data must be handled under segregated control by following the requirements of specific information classification. Personal data must not be made available outside the business without management authorisation.
Control over information transfer and distribution	Confidential information including personal data should be transported only by trusted party and protected by appropriate technical measures according to the predefined information classification.
Contract with contractors and trading partners	Personal data access by or transfer to third party should be based on a formal contract including at least a confidentiality (non-disclosure) agreement.

Table 6.4: Areas of security control for handling personal data

Table 6.4 summarizes the security control that underpins Principle 4 of the Ordinance for regulating the security of personal data and serves as complementary guidelines for data users. In addition to encryption and randomization of data, the following five areas of security control were implemented in YFTL to protect personal data:

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(i) **Ownership and responsibility**: The principle of this control area is to ensure proper division of responsibility, and check and balance in YFTL. The librarian is the business owner responsible for overseeing the implementation of library security policies. The IT officer of the library is the information systems owner overseeing the library systems and the technology infrastructure. As YFTL does not have a permanent security administrator, the information security consultant was appointed to implement the security controls indicated in library security policies.

(ii) **Classification of information**: Business information of YFTL was categorized and graded according to its confidentiality, integrity and availability. Each category was graded by the business owner as high, medium or low. For example, personal data of patrons such as data of birth and ID number are graded of high confidentiality, high integrity and highly availability, while book records of the library catalogue are graded as low confidentiality, high integrity and medium availability. The application of system hardware and software for the corresponding data was chosen according to the grade. For example, personal data is encrypted in the storage system but book records require no encryption.

(iii) **Information and process protection**: Special use of personal data can only be performed by dedicated library staff and any distributing outside the library is prohibited without approval from the librarian.

(iv) **Control over information transfer and distribution**: Data in the library system are not only stored on hard-disks, but also regularly backed-up on digital tapes that are stored at separated locations (offsite storage facility for the purpose of disaster recovery). The tapes storing highly confidential personal data are sealed in carry-case protected by digital pack-lock and are transported by an appointed security service provider, which was carefully selected by the library management.

(v) **Contract with contractors and trading partners**: Companies or individuals from outside the library who need to access personal data are required to sign a Non-Disclosure Agreement (NDA) with YFTL before accessing any personal data.

6.7   Conclusion and future development

Aiming to improve performance of small- and medium-sized libraries, a multi-tier implementation model for an RFID-based library system is presented. The model is realized through a generic ILS, which was designed with RFID/ISO technology and data-mining application. The ILS aims to not only automate the library operations, but also provide personalized information services with reference to patron preferences. To validate the feasibility of ILS, the system was implemented in YFTL, a medium-sized special library in Hong Kong. The analysis shows that the adoption of RFID-based LMS has resulted in improvement in performance. However, the personalized search engine carried the risk of breaking the data privacy law in Hong Kong. The library management employed a legal advisor and an information security consultant to help solve the problems. In accordance with the Personal Data (Privacy) Ordinance, the consultant proposed a list of security control measures to the library, including encryption and randomization methodology over personal data.

Customer privacy can be better protected when customer identity is not revealed and the customer can remain anonymous even after data mining. It is suggested that the current system platform can be further enhanced by creating an anonymous architecture to handle customer information.   With this architecture, customer identity is processed with encryption whenever data is imported to a data-mining module for analysis.   The encrypted identity data remains unique to each individual, but does not reduce the power of data mining, and can properly protect customer privacy. With this architecture, confidentiality of personal data can be preserved when data is released to third parties for research.

Chapter 7 CONCLUSION

7.1 Introduction

This chapter summarizes the conclusions of the four published refereed journal articles, discusses the research limitations, provides suggestions for further research, and finally summarizes the chapter and the thesis overall.

7.2 Conclusions drawn from the four articles

Each of the four research articles contributes to knowledge of and literature about lean principles adoption concerning firms in both manufacturing and services sectors along two different supply chain directions. Hence, two prominent lean approaches are reviewed and analyzed, based on related literature and empirical data obtained in the research. The outcomes of this research, including both individual and organizational adoption factors, are useful to firms planning to use this management system and practitioners who develop and implement adoption strategies with associated services. The following findings are suggested to answer the research questions identified in Chapter 1:

The first article, So and Sun (2010a), studies adopting lean principles in global manufacturing firms in networked supply chain by establishing the relationship between lean manufacturing adoption and electronically-enabled SCI. It addresses the following four research questions:

1. **What are the factors causing manufacturers to accept lean manufacturing?**

2. **How significant is the value of lean manufacturing perceived by manufacturers?**

3. **What impact does SCI have on the adoption of lean manufacturing?**

4. **What are the aspects of SCI that influence the adoption of lean manufacturing?**

The research questions can be answered by testing the significance of the research model and the hypothesized causal relationships, which are proved statistically satisfactory. The findings suggest that contextualizing EMSC in SCI positively influences the adoption of

lean manufacturing in a supply chain environment. According to the results, the relative advantage of lean manufacturing, which is represented in terms of its perceived characteristics, i.e. the value of lean manufacturing perceived by manufacturers, is the function of EMSC-enabled SCI, i.e. electronically-enabled supply chain integration, and significantly influences the adoption. In practice, supply chain functions related to decision support and transaction processing are readily supported by the information systems for lean manufacturing (Bozarth and Handfield, 2008). For example, e-kanban and efficient consumer response (ECR), driven by ERP/EDI systems, extend JIT/lean manufacturing along the supply chain and enable manufacturers and suppliers to work collaboratively toward lean objectives (Waters, 2009). The results indicate that implementing lean manufacturing in EMSC improves manufacturers' operation efficiency through integrating end-to-end supply chain information flow with the participation of both manufacturers and suppliers through joint investment in EMSC and running the operations over this common platform.

The findings also indicate that the two integration dimensions, i.e. organizational integration (internal SCI) and supplier integration (external SCI), are significantly correlated. With EMSC, organizational integration has direct influence on supplier integration and the value of lean manufacturing via perceived benefit which indirectly influence the adoption. Also, the end-to-end *e-kanban* replenishment signaling system can be implemented over the EMSC with signals traversed between upstream and downstream of the manufacturing supply chain over these integrated processes. This helps extend the value stream of lean manufacturing systems from manufacturers to suppliers that creates mutual benefit (Womack and Jones, 1996). EMSC, as the pipeline of information exchange in a supply chain and enabler of information integration, extend the value stream of lean manufacturing such as reducing lead-time, inventory and operation costs, beyond the internal operations of manufacturers. This information management capability adds value to suppliers who provide parts to manufacturers and to customers who purchase finished goods from manufacturers (Bozarth and Handfield, 2008; Womack and Jones, 1996). Hence, the findings suggest that electronically-enabled SCI influences lean manufacturing adoption positively by keeping the value stream flow and improving the relative advantage of lean manufacturing.

Last, but not least, the results indicate that, having job performance improved by adopting lean manufacturing, could bring manufacturers economic benefits and reinforce its

adoption. More importantly, the results show that the bottom-line of manufacturers could be improved if Buker's (1991) JIT management approach for lean manufacturing: i.e. *restructuring supply strategy*; *implementing pull production*; *streamlining manufacturing process*; and *workforce empowerment*, achieves results, as justified by the high explanatory power (R^2) of adoption and perceived benefits.

The second article, So (2010), is an extension of the first article by using the same empirical data set and studies the causal relationship between lean manufacturing adoption and supplier integration strategy, based on sound information management and supplier selection policy. The study addresses the following three research questions:

1. **Is adopting lean manufacturing in regular operations the sufficient condition for becoming sustainable practice?**

2. **What impact does collaborative information management for supplier integration have on the adoption of lean manufacturing?**

3. **What impact do supply policies have on the adoption of lean manufacturing?**

Based on the same quantitative approach used in the first article, both the research model and hypotheses demonstrate statistically significant results. The findings suggest that, based on Buker's (1991) JIT approach, lean manufacturing should be first adopted in regular use and demonstrate results in the following areas suggested by Buker, i.e. supply management, production management, process optimization, and empowerment of workforce before committing long-term use. The findings also suggest that lean manufacturing adoption is influenced by two EMSC capabilities, i.e. collaborative information management (post-implementation) and policy-based supplier selection (pre-implementation), offering manufacturers and suppliers information sharing and e-business transaction processing functions in supporting speedy and reliable information exchange in the supply chain. Besides, the findings agreed with Rogers' (1995) innovations diffusion theory (IDT) that on-going adoption of lean manufacturing as sustainable strategy is a long term commitment through a structural decision process from understanding, persuading, accepting, implementing, and confirmation of adoption.

Based on the previous studies of lean manufacturing (Black, 2007; Cagliano *et al*., 2006) and supply management (Bozarth and Handfield, 2008; Guimaraes *et al*., 2002), four indicators are used to study the supplier integration effect on lean manufacturing: i.e.

suppliers' delivery performance; *suppliers' ability to provide innovation and co-design support*; *suppliers' willingness to disclose cost and other information*; and *suppliers' historical performance*. These four indicators concern the essential supplier quality to fulfill the lean objectives, which can be used as the supplier selection criteria, in part of the supplier integration strategy. The results show that supplier integration is process oriented (pre- and post-implementation) and based on mutual trust (sharing planning and operation data and both parties investing in the EMSC) which are important to run lean manufacturing collaboratively. Relevant supplier integration strategy can be developed based on these process-focused capabilities through selecting and developing suitable suppliers with the competency of supporting lean manufacturing and, hence, the collaboration is then sustainable.

The third article, So and Sun (2010b), examines a successful case of adopting lean services enabling technology to apparel retailing by studying the implementation of RFID in the service operation of an apparel retailer through exploring user experiences. The study aims to answer the following three research questions:

1. **What are the adoption factors that cause the retailer to accept RFID?**

2. **What are the improvements that RFID brings to the retailer's operations?**

3. **What are the issues of implementing RFID in the retailer's operations?**

The results of the case study show that four major adoption factors in both organizational (compatibility and costs) and individual (ease of use and security and trust) aspects are identified by positioning RFID as an innovative technology in contrast to existing practice.

The first factor is *compatibility*, representing an important product determinant of technology adoption as it represents consistency with existing values, past experiences and needs of potential adopters (Rogers, 1995). As the factor influences product developers and merchants, their staff members were interviewed in the study. The compatibility of RFID technology was evaluated in terms of how compatible the technology is required with existing regulations, standards or practices for integrating with partners, sharing of resources or achieving lower product cost. The findings suggest that developers need to design RFID products complying with relevant standards or regulations of target markets as part of the industry requirements. Moreover, RFID is considered advantageous if it can interoperate with information systems that are commonly used in the retail business or,

more specifically, in apparel retailing. For example, ePOS systems (front-end application supporting transaction processing) and enterprise resources planning (ERP) systems (back-end application supporting inventory management, bill-of-materials and other business functions) are typical business applications used by retail companies. Besides, RFID is in a better position if it is compatible not only with these retail information systems but also the operation processes so that the merger of RFID to existing operations demands minimal effort in terms of lead-time and resources.

The second factor is *cost advantage* which essentially represents the economic benefit of a technology and is considered as a relative advantage influencing adoption (Rogers, 1995). The ability of driving product development cost down obviously brings competitive advantage to a RFID product developer, while it is also not difficult to explain that apparel retailers are more willing to adopt RFID technology if it really helps reduce their operation costs with low one-off investment. In fact, the findings suggest that seeking long-term operating cost savings is one of the reasons that the apparel retailer is implementing RFID technology.

The third factor is *perceived ease of use* (PEOU) which is another measure of adopting innovative technology by understanding if the technology is easy to use. PEOU is important to both staff members on the sales floor, who are responsible for daily store management, and customers for whom the new system is expected to give them a unique and 'hassle free' shopping experience. The findings reveal that first line support staff expect the new system could relieve their workloads, rather than needing their technical support. The merchant would expect the ease-of-use attribute of RFID technology to help capture the moment of truth to close the sales sooner.

The last factor, *security and trust*, are essentially the antecedents of PEOU and PU of the TAM (Hossain and Prybutok, 2008; Thiesse, 2007). The findings suggest that, when applying RFID in retail, it may involve security risks, for example, leakage of personal data, unauthorized use of personal data or fraud transactions, leading to reduction of trust in merchants. Yet, risks can be avoided or mitigated if RFID technology is adopted by taking proper security measures (So and Liu, 2006).

The fourth article, So and Liu (2007), studies a failed case of adopting lean services enabling technology to library operations through exploring the circumstances of implementing RFID in a library with the focus on issues of identification and resolution, as

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well as drawing conclusions and practical implications as insightful reference. The following three research questions are addressed in the study:

1. **What are the issues of implementing RFID technology in lean service operations?**

2. **What are the solutions to the issues of implementing RFID technology in lean service operations?**

3. **What are the practical implications of using RFID technology to improve customer services and streamline operations?**

The findings indicate that adopting RFID technology in the library resulted in performance improvement in operations management. However, the personalized search engine of the new library intelligent services aiming to improve customer values, carried the risk of breaking the data privacy law in Hong Kong. The library management employed a legal advisor and an information security consultant to help solve the problem. In accordance with the Personal Data (Privacy) Ordinance, the consultant proposed a list of security control measures to the library, including encryption and randomisation methodology over personal data. Customer privacy is protected when customer identity is not revealed and the customer can remain anonymous even after data mining. It is suggested that the current system platform can be further enhanced by creating an anonymous architecture to handle customer information. The findings indicate that awareness of regulatory compliance is important in acquiring new management practice from setting strategies, planning to implementation, as it could involve additional costs and lead-time for launching the new services jeopardizing the original purpose of improving service level and customer values. Thus, organization readiness in terms of human aspects is important to the success of lean services.

In sum, the objective of the thesis was to study the circumstances leading to successful adoption of lean principles by firms that create values relevant to their respective supply chain position. The adoption of lean principles is the theme of research within the four articles. By comparing and contrasting the findings on lean manufacturing and lean services, the following important conclusions are drawn based on the above findings:

(a) With the aim of eliminating wasteful processes and seeking value in a sustainable way, *organizational factors*, i.e. *compatibility* and *cost advantage*, can be the

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common objective of two different lean approaches. As indicated in the literature review in Chapter 2, value is represented by relative advantage of lean principles specified as economic profitability, and customer value obtained from products/services which is the common measure of two lean approaches. On the manufacturing side, Buker's (1991) JIT approach for lean manufacturing: (1) restructuring supply strategy, (2) implementing pull production, (3) streamlining manufacturing process, and (4) empowering workforce, create values to manufacturers by improving their bottom line, in which these competency areas can be adapted to lean services. One of the major values of Buker's (1991) JIT approach concerns process improvement that preaches simplicity through streamlining current processes and makes value flow from supplier, manufacturer and all the way to the customer (Harrison and Hoek, 2008). This concept can be applied to create lean services at the customer touch points. The findings indicate that EMSC as an information management platform for supply chain members enables external process integration between manufacturers and suppliers (supplier integration), and internal production process integration within a manufacturer (organizational integration). Based on the results, the integrations that lead to process simplification intensify the value of lean manufacturing and strengthen its adoption in practice, forming the basis of its ongoing adoption in the long run. Moreover, manufacturers may restructure their supply strategies such that only those companies who participate and invest in EMSC can become their suppliers.

(b) Adopting lean services at customer touch points is influenced by *individual factors* that are characterized by user experience such as "touch and feel", in which the nature is different to process integration which mainly concerns the competency of practice, for example, eliminating waste, streamlining operations, promotes fast changeovers and close supplier relationships. The individual adoption factors indicated in article three are based on the field experiences of end-users which are closely related to "usability", a knowledge domain dealing with the interactions between a human and a particular tool or other human-made object such as a door handle, a screw-driver, a computer or a computer-based product or service, in order to achieve a particular aim. The adoption factors, "*PEOU*" and "*Security and Trust*", indicated in the results of article three, are essentially the antecedents of the TAM (Davis, 1989) that explain the willingness of end-users in terms of the use and acceptance of technology or systems. These factors are helpful to practitioners designing user oriented services or technology in realizing lean principles appropriate for use in the field by considering human factors.

(c) People, in many cases, play an important role in organizational improvement, in which people's participation is crucial when adopting a new management system that brings profound impact to the entire firm, for example, introducing the lean principle. As indicated in the literature review in Chapter 2, process automation in lean manufacturing needs to incorporate human dynamics that involve individual skills and teamwork. As such, empowerment of workforce with this capability is important to the implementation success of lean principles and is considered as a focus area of implementation. The findings indicate that implementing lean principles necessitates evaluating the work that people do, either in a primary or support role, with respect to the value objectives specified for the service or product. Focusing on people in value creation means, of course, investing in upgrading the skill of staff through training and team building, so that the team is capable of designing their processes and solving problems to achieve real empowerment and ability to deliver a foolproof system at their workplace as discussed in Chapter 2. What occurred with the implementation issue discussed in the case study of article four demonstrates that the library staff may have lacked the skill and teamwork in designing the new services for the library. This resulted in additional costs of hiring professional consultants for problem resolution and the delay of the new services launch.

(d) Lean principles emphasize customer values and customers should not pay for the cost, time and quality penalties of wasteful processes and overheads in the supply network (suppliers) and production activities (manufacturers) that cascade all the way to the services at the customer touch points on the shop-floor (retailers) triggering, for example, delivery delay, which imply that lean services in the downstream supply chains are potentially influenced by the outcomes of lean manufacturing, concerning the upstream processes. On the other hand, communicating the demand by customer pull over a *kanban* linked-supply chain might improve lean manufacturing which, in-turn benefits lean services. Based on the findings and literature review in Chapter 2, the two different lean approaches might be mutually beneficial if objectives and implementation can be properly aligned. Hence, firms, no matter manufacturers or retailers, should use the same approach to adopting lean if by principles and practices carefully aligning the value and process steps. Grounded in the above conclusions, the approach is summarized into the following five steps:

[1] Specify the value that focuses on customer and business – Value is specified on two fronts: (a) from the customer perspective which may include *price*, *delivery speed* and *services*; and (b) from the business perspective

representing the value of shareholder and management which may include the *reduction of cost* and *inventory* or *acquiring new knowledge/skill*.

[2] Align value objectives with stakeholders in the company and trading partners in the supply chain (i.e. supply chain counterparts) – is a strategic move with all key players in the supply chain working towards the same target.

[3] Identify the value stream – the whole sequence of process steps in the supply chain with all the activities, no matter if value adding or non-value adding, should be identified for the next step.

[4] Make value flow in the supply chain – Wasteful tasks/processes are removed by lean principles. With Buker's (1991) JIT approach that includes (a) *processes integration through SCI and supplier integration*, and (b) *empowering people with skill and teamwork capabilities*, the tasks/processes improvement can be better supported.

[5] Enable customer pull signaling – By working collaboratively with suppliers and retailers to make only response to a signal from the customer based on Buker's (1991) approach: (a) restructure the supply strategy so that the new initiative is support by appropriate suppliers; and (b) implement a pull system by establishing kanban signaling to communicate actual demand to upstream.

In conclusion, this thesis contributes to knowledge about and the literature on lean principles adoption by extensive review and detailed analysis on the topic through empirically studying the circumstances in manufacturing and services that represent two supply chain directions, and by identifying the antecedents in both organizational and individual aspects leading to adoption. In addition, a five-step lean principles adoption approach is summarized, based on the empirical findings, with the objective of delivering this value-adding management approach to not only the firms in retailing and manufacturing, but also to their trading partners, as supply chain stakeholders, by improving the overall competitiveness of the entire supply chain.

7.3 Limitation of the research

As introduced in Chapter 1, the research is carried out in two supply chain directions, i.e. lean manufacturing and lean services. On this basis, the limitations are discussed as

follows.

There are a few limitations in the two studies on lean manufacturing. First, the studies examine lean principles and SCI from the standpoint of a manufacturing company (the firm in the upstream of EMSC). The constructs are not appropriate for distributors and retailers (the firms downstream of EMSC), as each construct includes one or more production centric item. Second, the implementation of lean manufacturing in a supply chain environment may be influenced by contextual factors, which are not covered in the studies. The factors may include *firm size*, *a firm's supply chain position*, and *experience involved in the use of lean principles in relation to various EMSC systems and technologies*. For example, the larger manufacturers (relevant to firm size) usually have more complex organization structures and supply chain networks (relevant to a firm's supply chain position) which normally demand more systematic processes, people with relevant experience, and comprehensive information systems to be in place for supporting a firm's operations that are becoming more complex in the networked business environment. These contextual factors are suggested for coverage in future studies.

Two further limitations of the studies concern the measurement of concepts. First, the use of a single respondent may generate some measurement inaccuracy. Second, the performance of eliminating manufacturing wastes depends heavily on the quality of EMSC. For example, Lee *et al.* (2009) emphasized that efficient data collection with high accuracy is the key to e-procurement in order to purchase the right material of the right quality from the right suppliers. Therefore, appropriate measurements, in formulating relevant supplier evaluation function, and integrating the system with existing purchasing functions smoothly, through capturing accurate requirements from both suppliers and end-users, should be incorporated into the supplier integration strategy over the EMSC infrastructure (Cheung and Liao, 2003; Lee *et al*., 2009).

There are some limitations in the last two studies. First, the primary limitation is the use of a single case study, as the research findings from a single case may not be generalizable to other cases or a larger population. Hence, the case study results are used for complementing the first two empirical studies through insights into customer values by capturing the user experience of using lean enabling technology. Second, the geographical focus on Hong Kong can be seen as a limitation. Conducting the research in different countries with a reasonable budget would most likely strengthen and validate the findings

of the studies. Third, the customer values captured in the studies are mainly related to the lean services, i.e. the topic of lean principles adoption. It is suggested to enhance the scope a bit further to cover the effect of lean services on the perceived values or perceived benefits of the intended products that customers want to buy.

7.4   Future research

Further research is recommended to improve upon and extend the two respective parts of the research. Future research areas are suggested primarily based on the limitations of the studies. First, firm size as a typical contextual factor that influences the implementation of lean manufacturing in a supply chain environment should be considered in forthcoming studies in order to examine lean principles adoption in firms of difference sizes. Also, future research should survey multiple respondents (SCM & logistics, IT and operations managers) from each organisation. Hence, the discrepancies of SCM and lean production perception between the groups, and the impact of such discrepancies on the overall result, can be examined. Further study is being conducted, and the associated research paper, "Supplier integration strategy for lean manufacturing adoption in electronic-enabled supply chains", authored by S. So and H. Sun, is published in *Supply Chain Management: An International Journal* (Volume 15, Issue 6, 2010).

Second, in addition to the time and cost of operation as the important measures of lean success, some lean practitioners propose customer satisfaction as an alternate measure (Plenert, 2007). On this basis, future study can compare customer relationship management (CRM) against supplier integration in the EMSC environment that influences the adoption of lean production. The empirical results will help integrate manufacturers' upstream suppliers and downstream customers towards lean manufacturing objectives. Besides, measures on lean practice in other human aspects, such as relationship management, can be investigated in future studies so that manufacturers will know if people's capabilities can be improved. This is the value that TPS originally advocated (Sugimori *et al.*, 1977). Third, research items on evaluating the efficiency and accuracy of e-procurement for acquiring suitable materials from the right suppliers will be derived in future research by finding additional items, or even replacing the original set of variables, to measure these concepts, in order to establish an improved construct validity (Hair *et al.*, 1998).

Future research is also suggested in relation to the last two studies based on the limitations

identified previously. First, generalizing the case study outcomes can become part of the research objectives, for example, testing the business value-added model proposed in the third article. This limitation can be overcome by case study tactics suggested by Yin (2009), by using theory in single case studies or replication logic in multiple case studies. Furthermore, a survey on a random sample, with a carefully selected unit of analysis in service and retail segments, is suggested, so that generalizability of the proposed model can be tested with well established quantitative research methods. Second, the burgeoning use of RFID technology in other Asian countries, such as China, Singapore, Korea and Japan, may offer an opportunity to conduct studies overseas with an appropriate budget, that help validate the research findings. Last, the scope of future research may be extended to understanding the lean services effect on the values of products being purchased, by developing relevant measures in the survey so that the findings can serve as a reference to marketers and product developers. A research paper addressing some of these limitations, "A Novel RFID Application for Realizing Lean Services Based on Customer Chain Operations Reference Model", authored by S. So, is just accepted by *The IEEE International Conference on Industrial Engineering and Engineering Management*, in the topic of service innovation and management. The conference will be held from 7th to 10th of December, 2010 in Macao, The People of Republic of China.

7.5 Summary

Lean principles is a management system using a pull method and the philosophy behind it is to link the value stream between the upstream and downstream supply chain by communicating the actual demand through the *kanban* signal. An integrated e-supply chain essentially provides lean enterprises a platform to achieve this objective. Establishing the kanban-linked supply chain, demands information that reflects customer value is made available across the supply chain. On this basis, the current thesis studies the adoption corresponding to firms' supply chain position by identifying the circumstances and antecedents in both individual and organizational aspects. The adoption of lean principles are measured based on Buker (1991)'s JIT approach which includes the supply strategy, process integration, pull production, and workforce empowerment. Each of these management competencies create value to manufacturers including cost saving, lead-time reduction, and inventory reduction. Extending the value to manufacturers' trading partners or their supply chain counterparts is necessary in order to increase the competitiveness of

the entire supply chain.

As discussed in the published refereed articles, EMSC integrates information flow in the supply chain and helps extend the value stream of lean manufacturing systems from manufacturers to suppliers that create mutual benefit. EMSC-enabled SCI keeps the value stream flow in the supply chain that improves the value of lean manufacturing and strengthens its adoption. The process approach is further evaluated by relating the relationship of supplier integration with lean manufacturing adoption in the second article, through selecting and developing suppliers with collaborative information management capabilities. The relevant supplier integration strategy can be developed to help maintain long-term supplier relationships. The last two articles focus mainly on the human aspect that influences lean services adoption by showing the importance of user experience and workforce empowerment, as emphasized by Sugimori (1977) and Ohno (1988). Human factors such as PEOU and Security and Trust, based on user experience, as well as skill and teamwork, as a result of workforce empowerment, are the antecedents of lean adoption that influences the value flow, essentially representing a form of business value that can enhance the performance of lean manufacturing or lean services.

Lastly, the finding on lean services adoption is compared and contrasted with the results of lean manufacturing studies which are not addressed by previous studies. This thesis contributes to practice through putting together the value creation steps, based on the research findings, such that a systematic process of adopting lean principles to business in the supply chain context is created. The five-step procedure from (1) specifying value, (2) aligning value objective, (3) identifying value stream, (4) making value flow, to (5) making customer pull, is essentially developed for any type of business that aims to improve the overall efficiency of the supply chain and to enhance the work environment.

APPENDICES

There are five appendices in this section, including the questionnaire of manufacturing strategy survey, the formulas and abbreviations used in this thesis, the glossary of terms, and lastly the four journal articles in their original formats.

Appendix A – Questionnaire of manufacturing strategy survey

Description of the business unit

a | What best describes your business unit? Tick one.
____ Company ____ Division ____ Plant ____ Other

b | What are the name, origin and size of the corporation of which your business unit is a part?
Name_____ Origin (headquarters country) _____
Size (# of employees): Local plant _____ Country _____ World _____

Lean Supply Strategy

		Low				High
1	What is level of investment on Extranet/EDI/B2B systems for operation coordination from your suppliers?	1	2	3	4	5
2	What is level of investment on Extranet/EDI/B2B systems for operation coordination from your company?	1	2	3	4	5
3	What is the extent of information sharing about inventory level with your suppliers?	1	2	3	4	5
4	What is the extent of information sharing about production planning decisions and demand forecast with your suppliers?	1	2	3	4	5
5	What is the level of importance on selecting your suppliers based on the criteria of delivery performance (reliability, speed, flexibility)?	1	2	3	4	5
6	What is the level of importance on selecting your suppliers based on the criteria of ability to provide innovation and co-design?	1	2	3	4	5
7	What is the level of importance on selecting your suppliers based on the criteria of willingness to disclose cost/other information?	1	2	3	4	5
8	What is the level of importance on selecting your suppliers based on historical performance?	1	2	3	4	5

Continued Adoption of Lean Principle as Sustainable Manufacturing Practice

9	What is the degree of use in last 3 years on restructuring supply strategy and the management of your suppliers portfolio towards lean manufacturing?	1	2	3	4	5
10	What is the degree of use in last 3 years on implementing pull production towards lean manufacturing?	1	2	3	4	5
11	What is the degree of use in last 3 years on restructuring your manufacturing processes and layout to obtain process focus and streamlining towards lean manufacturing?	1	2	3	4	5
12	What is the degree of use in last 3 years on the empowerment of your workforce towards lean manufacturing?	1	2	3	4	5
13	What is the degree of expected use within next 3 years on restructuring supply strategy and the management of your suppliers portfolio?	1	2	3	4	5
14	What is the degree of expected use within next 3 years on pull production towards lean manufacturing?	1	2	3	4	5
15	What is the degree of expected use within next 3 years on restructuring your manufacturing processes and layout to obtain process focus and streamlining towards lean manufacturing?	1	2	3	4	5
16	What is the degree of expected use within next 3 years on the empowerment of your workforce towards lean manufacturing?	1	2	3	4	5

Appendix B – Tables of formulas

Table B1 - Model fit assessment methods in structural equation modeling (SEM)		
Statistical method	**Purpose of use in the study**	**Descriptions**
χ^2 goodness of fit statistic		
χ^2 goodness-of-fit test	To test the model fit by assessing magnitude of discrepancy between the sample and fitted covariance matrices (Hu and Bentler, 1999)	χ^2 goodness of fit statistic is denoted as the product of the sample size minus one and the minimum fitting function: $$T = (N-1)\,F_{min}$$ where the T statistics (called χ^2 by other researchers) has an asymptotic (large sample) χ^2 distribution under an assumed distribution and the hypothesized model for the poulation covariance matrix. Because χ^2 is sensitive to sample size and, due to our large sample size (n = 565), an alternative of normed chi-square (χ^2/df) is used to assess the model fit in our studies.
fit indexes (absolute)		
Root mean square error of approximation (RMSEA)	To test the model fit by assessing how well an apriori model reproduces the sample data (Hu and Bentler, 1999)	Absolue fit indexes do not use reference model to assess the amount of increment in model fit, in which tye formula of RMSEA is expressed as: $$RMSEA = \sqrt{\hat{F}_a\Big/df_T}\,,\text{ where }\hat{F}_a = \max\left[(T_T - df_T)\big/(N-1),\,0\right]$$ in which the statistic has a known distribution and compensates for the effect of model complexity and noncentrality-based.
fit indexes (incremental)		
Tucker-Lewis index (TLI) or nonnormed fit index (NNFI)	To test the model fit by measuring the proportionate improvement in fit by comparing a target model with a more restricted, nested baseline model (Hu and Bentler, 1999)	NNFI is nonnormed in which the value can fall outside the 0-1 range and the formula is expressed as follows: $$TLI\ (\text{or }NNFI) = \frac{[(T_B/df_B)-(T_T/df_T)]}{[(T_B/df_B)-1]}$$ where the statistic can compensate for the effect of model complexity.
Comparitive fit index (CFI)	Another type of incremental fit index which is an estimate of the noncentrality parameter and can be obtained as the difference between the statistic and its associated degrees of freedom (Hu and Bentler, 1999; Kaplan, 2000)	CFI is normed in which the value falls inside the 0-1 range and the formula is expressed as follows: $$CFI = 1 - \frac{\max[(T_T - df_T),0]}{\max[(T_T - df_T),(T_B - df_B),0]}$$ where the statistic is noncentrality-biased.

Table B2 - Measurement methods for reliability and validity assessment

Statistical method	Purpose of use in the study	Descriptions
Cronbach's alpha test	The measurement is essentially a reliability test which assess the degree of consistency between multiple measurements of a variable or item ranging from 0 to 1, with values of 0.60 to 0.70 deemed the lower limit of acceptablity (Hair et al., 1998).	The statistic is defined in the following formula: $$\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N}\sigma_{Y_i}^2}{\sigma_X^2}\right)$$ where N is the number of components or items, σ^2_X is the variance of the observed total test scores, and $\sigma^2_{Y_i}$ is the variance of component i. The cronbach's alpha statistic is normally obtained by the SPSS computer program which is used for statistical analysis.
Factor analysis	The measurement is primarily used for data reduction and summarization, in which the results can be applied to assess the validity of measurement scales (Hair et al., 1998). Convergent validity is assessed in the study by evaluating the significance of factor loadings which represents the degree to which two measures of the same concept are correlated (Anderson & Gerbing, 1988; Hair et al., 1998).	The common factors themselves can be expressed as linear combinations of the observed variables as indicated by the following formula: $$Fi = W_{i1}X_1 + W_{i2}X_2 + W_{i3}X_3 + \ldots + W_{ik}X_k$$ where F_i represents the estimate of i th factor, W_i is for the weight or factor score coefficient and k is the number of variables. The statistics is obatinable by using the SPSS computer program.
Kaiser-Meyer-Olkin (KMO) test	The KMO measure of sampling adequacy is an index used to examine the appropriateness of factor analysis, and the KMO values between 0.5 and 1.0 indcate factor analysis is appropriate (Kaiser, 1974).	The index is realized through comparing the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. The KMO statistic can be obtained by SPSS computer program through conducting factor analysis.
Average variance extracted (AVE)	The AVE measure assess the discriminant validity of constructs in the study by measuring the extent to which constructs are different (Campbell & Fiske, 1959; Fornell & Larcker, 1981)	The AVE measures are normally obtained by the statistical software, LISREL. However, the statistic can be calculated as follows: The total of all squared standardized factor loadings / the number of items As indicated in the text, the square root of AVE by each construct exceeds the corresponding inter-variable correlation demonstrates acceptable discriminant validity (Fornell & Larcker, 1981).

Table B3 - Measurement methods for model assessment

Statistical method	Purpose of use in the study	Descriptions
Multiple regression model	To provide estimates of how much variance in the dependent variables are accounted for by variance in the independent, or predictor, variables (Allen et al., 2009)	Multiple regression model can be represented by the following generic equation: $$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \cdots + \beta_i X_i + C.$$ where the predictor variables are denoted by X, their associated coefficients are denoted by β and C represents a constant. There are two regression models in the study. Model 1 concerns the continued adoption of lean manufacturing as sustainable practice, while model 2 is related to the influence of lean supply strategy on the use of lean manufacturing.
F-test	To test the goodness of predictions of the multiple regression models (Allen et al., 2009)	The significance of R^2 (i.e. multiple correlation coefficient) is tested by using F statistics. The association can be evaluated by the following fomula and then the critical values for the F distribution: $$F_{m,n-m-1} = R^2/(1 - R^2)\,((n - m - 1)/m)$$ where m repesents the number of predictor variables and n represents the numbers of events in the study.
t-test	To test the goodness of the coefficient estimates of the multiple regression models (Allen et al., 2009)	The significant of β weights which determines the relative contribution of each predictor variable is evaluated by the t-test with the following formula: $$t = \beta/s_\beta, \text{ and } s_\beta = \{ (1 - R^2) / [(n - k - 1)(1 - r_{12}^2)] \}^{\frac{1}{2}}$$ where s_β is the standard error of beta, k is the number of variables, and r_{12}^2 is the squared multiple correlation coefficient of the predictor variables.

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Appendix C – Abbreviations used in thesis

AVE	Average Variance Extracted
B2B	Business-to-Business
CFI	Comparative Fit Index
CRM	Customer Relationship Management
EDI	Electronic-Data Interchange
EMSC	Electronically-enabled Manufacturing Supply Chain
ETO	Engineering-to-Order
ERP	Enterprise Resources Planning
IDP	Innovation Decision Process
IDT	Innovation Diffusion Theory
IT	Information Technology
JIT	Just-in-Time
KMO	Kaiser–Meyer–Olkin
MRA	Multiple Regression Analysis
NNFI	Nonnormed Fit Index
PB	Perceived Benefits
PCA	Principal Component Analysis
PEOU	Perceived Ease of Use
PU	Perceived Usefulness
R&D	Research and Development
RFID	Radio Frequency Identification

RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equation Modeling
SCI	Supply Chain Integration
SCM	Supply Chain Management
TPS	Toyota Production System
WIP	Work-In-Process

Appendix D – Glossary of terms

Autonomation

An approach of automating the production processes with a human touch. Intelligence is added to equipment to prevent the production of defective products, eliminate overproduction, and automatically stop the process when abnormalities are detected. This type of automation frees people to perform more valuable activities.

Buffers

The use of inventories, extended lead times, or other methods intended as a means for preventing schedule delays from impacting adjacent processing steps or customers. Buffers act as a significant source of lag.

Build-to-order (BTO)

The manufacturing method of waiting until an order is placed to make or assemble the product, and only in sufficient quantities to fill the order with very little overage. This prevents having to store unsold items until needed. *See also* build-to-stock (BTS) and engineering-to-order (ETO).

Build-to-stock (BTS)

The manufacturing method of making commodity-type products in advance and keeping them in stock until they are ordered. *See also* build-to-order (BTO) and engineering-to-order (ETO).

Business-to-business (**B2B**)

It describes commerce transactions between businesses, such as between a manufacturer and a wholesaler, or between a wholesaler and a retailer. In a typical supply chain environment, B2B transactions involve the trading of subcomponent or raw materials in association with the sale of one finished product to the end customer.

Continuous flow

The ideal state where products move through a manufacturing process — or people move through a service process — one at a time, without stopping or waiting. It is also known as one-piece flow and "make one, move one."

Defects

The output of a process that fails to meet the required specification or performance standard. One of the seven forms of waste. *See also* seven kinds of waste.

Effectiveness

It is the utilization of the minimum number of resources, with the least amount of waste, to create a defined value for the customer.

Electronic Data Interchange (EDI)

It is the firm's capability to receive orders, send delivery notifications and invoices, receive payments, and so on by computer in B2B transactions. *See also* business-to-business

(B2B).

Engineering-to-order (ETO)

The products whose customer's specifications require a unique design, such that significant customization and/or so-far unused purchased material are typical of this kind of manufacturing method. *See also* build-to-order (BTO) and build-to-stock (BTS).

Enterprise Resource Planning (ERP)

It is an information system used in business to gather data from across multiple functions in a company. ERP systems monitor orders, production schedules, raw material purchases, and finished goods inventory. ERP systems are good at tracking data but generally do not have the more complex capability to analyze it.

E-procurement

The ability to complete purchasing functions online, usually on a secure Web site where vendors put their product catalogues, order forms, and other data for customers or supply chain partners to access. This involves the use of B2B enabling technology, such as EDI. *See also* business-to-business (B2B) and Electronic Data Interchange (EDI).

Flow

It is the movement of a product or service along the value stream, from its inception to the customer that builds up of value. Smooth flow is indicated by the absence of defects, out-of- station work, and other delays; it is indicated by low cycle time variation.

Information flow

It is the movement of accurate, timely information to the right people at all levels and points across the value stream.

Innovation-decision process (IDP)

The process through which an individual (or other decision-making unit) passes from first knowledge of an innovation to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation and use of the new idea, and to confirmation of this decision.

Innovation flow

The progression of improvements and new technologies into products and services.

Inventory

The raw materials, purchased parts, work-in-process components, and finished goods that are not yet sold to a customer. Inventory is one of the seven forms of waste, when the amounts exceed the minimum level to maintain the pull system. *See also* seven kinds of waste.

Just-in-time (JIT)

Providing what is needed, when it is needed, in the quantity needed, and the quality level needed.

Kanban

A signal that triggers replenishment or withdrawal in a pull system. *Kanban* is often in the form of a card on a container in production environments. The signal regulates the production flow in the value stream. The concept of *Kanban* has been extended to supply chain operations for making the value stream flows end-to-end from suppliers to final-customers. *E-Kanban*, an electronic version of *Kanban*, makes use of information system, for example, *Enterprise Resources Planning* (ERP) system, to implement the pull concept.

Lead time

It is the elapsed time from the initial stage of a project or policy and the appearance of results. In the case of a product environment, the time from order receipt to shipment to the customer for one product.

Lean

An improvement methodology based on a customer-centric definition of value, and providing that value in the most effective way possible, through a combination of the elimination of waste and a motivated and engaged workforce. The concept of lean is a generic process management philosophy originated in manufacturing derived mostly from the Toyota Production System (TPS). *See also* Toyota Production System (TPS).

Material flow

The movement of raw materials and product through the process steps of a value stream.

Motion

Any movement of people's bodies that does not add value to the process. One of the seven forms of waste. *See also* seven kinds of waste.

Muda

A Japanese word of waste represents any activity that consumes resources, but creates no value. Muda is categorized in two forms: Type-1 muda is necessary for the process, but non- value-added; type-2 muda is both unnecessary and non-value-added.

Non-value-added

Any activity, product, or process that does not meet the value-added criteria. *See also* Muda and value-added.

Overproduction

Producing more than the customer requires. One of the seven forms of waste. *See also* seven kinds of waste.

Perfection

The complete elimination of waste so that all activities along a value stream create value.

Process

It represents a set of activities, material, and/or information flow that transforms a set of inputs into defined outputs.

Procurement

The range of activities a company undertakes to select and qualify suppliers, negotiate prices, and engage in other pursuits related to the purchasing of goods and services. *See also* E-procurement.

Pull

A system of production that is activated by customer demand, which signals all the upstream activities to build to replenish what has been used. Upstream activities do not do anything until the signal from downstream is received.

Relative advantage

The degree to which a new idea is perceived as better than the idea it supercedes.

Seven kinds of waste

Transportation, waiting, overproduction, defects, inventory, motion, and excess processing are the seven forms of waste identified by Taiichi Ohno, one of the pioneers of the Toyota Production System, as waste normally found in mass production. Also known as the seven wastes or the seven *mudas. See also* Muda.

Standardized work

The definition of a process step represents a set work sequence and established in-process inventory. Deviations to standardized work constitutes an abnormality, which is then an opportunity for improvement.

Supplier

It is an individual or business entity that provides an input to a process in the form of resources or information.

Supply chain

A combination of the companies and their business activities needed to design, make, deliver, and use a product or service.

Supply chain integration (SCI)

It is the ability of companies in a supply chain to share data and synchronize business functions using technology, in order to perform more efficiently or cost-effectively. Enterprise systems used in a B2B environment including ERP and EDI play a significant role in SCI. *See also* Electronic Data Interchange (EDI) and Enterprise Resources Planning (ERP).

Toyota Production System (TPS)

A production system developed by the Toyota Motor Corporation based on the philosophy that the ideal condition for production is created when machines, facilities, and people work together adding value without creating waste. The two pillars of the Toyota Production System (TPS) are *JIT* and *autonomation*, which involves **automating the processes with intelligence** through incorporating human touch. *See also* just-in-time (JIT) and autonomation.

TPS

See <u>Toyota Production System (TPS)</u>.

Transportation

Unnecessary movement of materials or other items from one place to another, usually to storage or staging areas. *See also* <u>seven kinds of waste</u>.

Value

The worth placed upon goods or services, as defined by the customer. *See also* <u>Muda</u> and <u>non-value-added</u>.

Value-added

It is defined by the customer and the customer must be willing to "pay" for it. Payment is generally thought of in monetary terms, but could also include time or other resources.

Value stream

It is the flow of materials and information through a process to deliver a product or service to a customer.

Vertical integration

A traditional supply chain system in which a company owns or manages as many parts of its supply chain as possible, in order to gain maximum efficiency through economies of scale.

Visibility

A term for the sharing of data and other information among all the companies in a supply chain for their mutual benefit; sometimes referred to as "transparency."

Waiting

People in a process delayed or stopped because of process waste or ineffective process design. *See also* <u>seven kinds of waste</u>.

Waste

It stands for any activity that uses resources, but creates no value for the customer.

WIP

See <u>Work-In-Process (WIP)</u>.

Work-In-Process (WIP)

It stands for in-process inventory.

<u>**ACKNOWLEDGEMENT**</u>

Appendix E – Four journal articles: cover pages and acceptance letters

The first page and acceptance letter of each journal article are included in this appendix.

An extension of IDT in examining the relationship between electronic-enabled supply chain integration and the adoption of lean production

Stuart So* and Hongyi Sun

Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong, Kowloon Tong, Hong Kong

Lean production is proved to be an effective tool for companies to improve continuously and is widely studied from both practical and theoretical perspectives. However, most previous studies of lean production are limited to internal operations of a company. The research in this paper aims to explain the relationship between electronic-enabled supply chain integration and the adoption of lean production. A theoretical model with six hypotheses was proposed based on the innovation diffusion theory (IDT). The model was empirically tested with data from 558 manufacturers. The results show that: (1) IDT can explain lean production adoption; and (2) electronic-enabled supply chain integration positively influences the perceived relative advantage of lean production and consequently leads to its long-term adoption. This study uses IDT to explain lean production adoption with the influence of electronic-enabled manufacturing supply chain (EMSC). The study also has a practical implication that may change the supply policy in future practices, as companies may require their suppliers to implement EMSC as part of the lean production requirements.

Keywords: EMSC; JIT; manufacturing supply chain; kanban; lean production

1. Introduction

Bayou and Korvin (2008) simply defined, 'to be lean is to cut fat' which pinpointed accurately the purpose of this contemporary management philosophy. Lean principles preach simplification and elimination of wasteful processes, which are applicable to overly-complex and non-integrated organisation processes that are inefficient and provide little added value to customers. Becoming a lean enterprise enables manufacturers to improve throughput, reduce costs, and deliver shipment with shorter lead times. Today, manufacturers deal with more complex and longer supply chains, yet customers demand higher product variety at lower cost and shorter lead times. Manufacturers realise that non-integrated manufacturing processes and poor relationships with suppliers and customers in the supply chain are inadequate. The lean enterprise cannot afford low visibility or poor coordination across its global manufacturing supply chain. A new method is needed for manufacturers to stay competitive in their markets. Supply chain management (SCM), a set of integrated approaches helps manufacturers improve the total effectiveness of planning and operations from procurement of raw materials to producing

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Preview

From: j.e.middle@lboro.ac.uk

To: stuart.so@cityu.edu.hk, stuart.ck.so@gmail.com

CC:

Subject: Acceptance of your revised paper ID TPRS-2009-IJPR-0423.R1

Body: 04-Oct-2009

Dear Mr. So:

Ref: TPRS-2009-IJPR-0423.R1, "An extension of IDT in examining the relationship between electronic-enabled supply chain integration and the adoption of lean production" by So, Stuart; Sun, Hongyi

Our referees have considered the revised version of your paper and have recommended publication in International Journal of Production Research. We are pleased to accept your paper in its current form, which will now be forwarded to the publisher for copy editing and typsetting.
You will receive proofs for checking, and instructions for transfer of copyright and off-print copying in due course.

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Sincerely
John Middle
Editor, International Journal of Production Research
j.e.middle@lboro.ac.uk

Date Sent: 04-Oct-2009

⊠ Close Window

Adopting lean principle as sustainable manufacturing strategy in an electronic-enabled supply chain environment

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Abstract: This paper empirically examines the influence of lean supply strategy implemented in electronic-enabled manufacturing supply chains (EMSC) on lean manufacturing adoption in a sustainable manner. Adopting lean manufacturing often not only requires a lengthy period but also involves a prolonged decision process which makes sense to identify the antecedents for improving decision making. The influential factors including information sharing and use of e-business system in supplier integration together with lean performance-based supplier selection were tested with statistical methods based on survey data. It was found that lean manufacturing adoption is positively influenced by all these factors. Moreover, the results revealed that manufacturers may commit ongoing use of lean principle only if it has been adopted as regular practice. Lastly, managerial implications and future research were discussed to alleviate practical concerns in the execution of waste-reducing lean supply strategy and to explore the potential of developing reverse logistics on this platform.

Keywords: EMSC; electronic-enabled manufacturing supply chains; manufacturing supply chain; lean manufacturing; sustainability.

Biographical notes: Stuart C.K. So is a Research Follow in the Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong. His research interests include technology adoption and innovations diffusion, SCM and logistics, lean manufacturing and sustainability, RFID technology, information systems management and security.

1 Introduction

Sustainability constitutes of environmental, social and economic dimensions in which waste management is one of the major challenges along the three dimensions (United

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Guest Editor of
International Journal of Sustainable Economy
(ISSN Online: 1756-5812 and ISSN Print: 1756-5804)

Bari, 13th November 2009

Dr. Stuart SO

City University of Hong Kong

Letter of acceptance

This is to certify that the paper entitled: *Adopting lean principle as sustainable manufacturing strategy in an electronic-enabled supply chain environment* by Stuart So, City University of Hong Kong, has been accepted for publication in the forthcoming special issue "Sustainable Practices for Industrial Sectors and Regional Development" of *International Journal of Sustainable Economy*.

Prof. Giovanni Lagioia
Gust editor of special issue of IJSE

Creating ambient intelligent space in downstream apparel supply chain with radio frequency identification technology from lean services perspective

Stuart C.K. So* and Hongyi Sun

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Abstract: Radio frequency identification (RFID) technology realises ambient intelligence (AmI) in real life and offers not only user-friendly shopping experience to customers, but also agile and responsive store operations to merchants. Applying lean services in apparel retail operations may equally benefit to this industry. In this research, recent studies on RFID technology adoption were evaluated to help develop research instrument. It followed by a comprehensive case study on the implementation of an RFID-based smart retail system in an apparel retailer. Four adoption factors of this new initiative from both individual and organisational perspectives were identified:

1 compatibility
2 costs
3 ease of use
4 security and trust.

A business value-added framework was then proposed for further research based on the adoption factors and lean improvement objectives. Lastly, managerial implications were discussed with the aim to provide insights of better adopting this technology through the alleviation of practical problems and user concerns.

Keywords: ambient intelligence; AmI; apparel manufacturing supply chain; mix-and-match; radio frequency identification; RFID; user adoption.

Biographical notes: Stuart C.K. So is a Research Fellow at the Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong. His research interests include technology adoption and diffusion, information system security and RFID technology.

Hongyi Sun is an Associate Professor at the Department of Manufacturing Engineering and Engineering Management, City University of Hong Kong. His research interests include management of innovation and technology, quality management and manufacturing strategy.

International Journal of Services Sciences

Special issue on: "Innovative Information Technology in the Service Sector"

Saturday, October 03, 2009

Dear Dr. Stuart CK So and Prof., Dr. Hongyi Sun,

We are pleased to inform that your research work titled as *"Creating ambient intelligent space in downstream apparel supply chain with radio frequency identification technology from lean services perspective"* has been accepted to be included in the special issue of Int. Journal of Services Sciences. Issue will be published within following six months time period. Congratulations from your achievement, and looking forward for your continuous support for the IJSSCI journal in the future.

Special Issue Editors,

Sandor Ujvari
Dr., Senior Lecturer
Univ. of Skövde (Sweden)

Olli-Pekka Hilmola
Prof., Docent, PhD
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Learning from failure: a case study of adopting radio frequency identification technology in library services

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Abstract: One of the biggest myths about technology is the idea that any company can easily embrace it and comfortably expect results. However, successful implementation of a technology for an organisation depends on many factors and organisation readiness is most important. The readiness of strategy, people, process and system maturity should be assured for implementing the technology successfully. Radio Frequency Identification (RFID), an automatic identification technology that aims at enhancing customer experience and improving operation efficiency, is now widely used in many business sectors. It is not uncommon that problems, such as privacy issues in handling customer information and changes in workflow, appear in various RFID applications. This article attempts to give a brief introduction to this technology, highlight possible issues in its implementation and develop strategies to tackle the problems. A case study is presented, analysing the organisation's readiness for adopting RFID technology in a medium-sized library. Future improvement is proposed through learning from implementation failure.

Biographical notes: Stuart C.K. So is the Computer Systems and Laboratory Officer in the Department of Logistics at The Hong Kong Polytechnic University, involved in research and technology management. He received his Master of IT Management in 1999 and Master of Business Administration in 2003 both from the Macquarie University and his Master of Electronic Commerce in 2002. Mr. So's current research areas concern technology management in logistics, supply chain management and electronic business. He

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11 December 2006

Dear Stuart

Learning from Failure

I am pleased to inform you that your paper "Learning from failure: A Case Study of Adopting Radio Frequency Identification Technology in Library Services" has been accepted for publication in the *International Journal of Technology Intelligence and Planning*. It will be published in the special issue 'Failure, decision-making and technology management' in 2007.

Thanks for your contribution to the special issue and the journal.

Best wishes

Jacqueline Kam

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